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AUGUSTE FREDERIC BARTHOLDI.

THE author of the Statue of Liberty, in New York harbor, of whom we to-day present a striking picture, from *La Illustration*, was born in Alsace, April 2, 1834. The idea of the statue was first conceived by him in 1865. He had at that time obtained some distinction as a sculptor; and his republican ideas, and acquaint-

in 1884, and the statue formally turned over to the representative of the United States in Paris.

For full details of the statue and its pedestal, illustrated by elaborate engravings, we refer our readers to SCIENTIFIC AMERICAN SUPPLEMENT, No. 564. Bartholdi himself chose Bedlow's Island, where it stands, as the most fitting site for his great monument. The pedestal is a graceful and substantial structure, neither

TORPEDOES.

PREFACING a more comprehensive review of the torpedo question, which we hope to present our readers at an early date, the importance given the results of the recent experiments in Portsmouth Harbor against the Resistance requires careful consideration by our authorities before accepting them as conclusive evi-



BARTHOLDI—AUTHOR OF THE STATUE "LIBERTY ENLIGHTENING THE WORLD."

ance and friendship with those who were anxious to encourage more intimate relations between France and the United States, caused him to keep it constantly in view. The Franco-German war, in which he bore a part, and which resulted in the cession of his native province to Germany, only seemed to delay the execution of the project, but in no way remove it from his thoughts. In 1874, after a visit to America, during which Bartholdi found that his idea was warmly received, subscription lists were opened in France for the collection of the necessary funds, nearly all the contributions being in small amounts.

The actual modeling of the statue was begun in 1875, but it was not until 1879 that sufficient funds had been subscribed for its completion, which was accomplished

monotonous nor heavy, and does not really look to be as high and as large as it is. Its topmost platform is 39 feet square and 154 feet above low water mark, the statue itself being 151 feet to the top of the torch, and the total height being 305 feet.

Touching the artistic merit of the statue, or the value of the idea for which it stands, there seems to be at present no disposition in any quarter for anything except commendation; while there can be no question but the tact, energy, and perseverance of M. Bartholdi have won for him a phenomenal success among the sculptors of the present age.

THE first American patent for printing two or more colors at one impression was granted in 1844.

dence for or against this system of attack. The experiment made November 2 with the 16 in. Whitehead torpedo was apparently made under circumstances which were most favorable to the torpedo. Without risking the lateral deviations inherent in this type to so marked a degree, or the probable rebounding of the torpedo from the ship's side before explosion, this Whitehead was not fired from its gun, but was lashed in a longitudinal direction to the ship's bottom, near the bilge keel, about 8 ft. from the water line, and was exploded directly in contact. It contained 93 lb. of gun cotton, and was laid sufficiently under the waterline to insure supposed destruction. That it did not, must of course startle not only the majority of artillerymen, but particularly those enthusiasts who give mar-

velous ranges to the power of submarine projectiles. Many will urge that this last experiment must be accepted as a death blow to any torpedo system, for while they did expect the net to be of use when placed at a reasonable distance from the ship's side, they were confident that the explosion of the ordinary charge of the 14 in. or 16 in. Whitehead torpedo would completely destroy any ship with which it came in contact. We are not sure but that they are right in this opinion, for, carefully as the Resistance experiments seem to have been made, it does not appear to us that they were carried on under fighting conditions.

The results, however, will prove a serious lesson to torpedo champions, and demonstrate to all other enthusiasts that not only the torpedo cannot take the place of all other weapons, but neither is there any other one arm that can be solely relied upon for either offensive or defensive success.

It would be as absurd to take a ship into action with but one type of weapon as to send a doctor to sea with but one medicine. A captain must be prepared for the various situations in which he may be placed, selecting that instrument which will best meet the circumstances.

In Mr. Jaques' "Torpedoes for National Defense," which is evidently one of numerous reports that he has prepared for the Naval Department or Congress of the United States, we find many pertinent statements which show that he has endeavored to review this question as comprehensively and without prejudice as other subjects to which we have already referred. In regard to this question, he says, "The most powerful torpedo system that can be conceived cannot take the place of all other defenses. Ships both armored and unarmored are indispensable to prevent blockade and to destroy commerce. The three lines—fortifications, torpedoes, and ships—are absolute requisites of a proper and sure defense, and heavy guns are imperative, not only for these ships, but to prevent countermining, removal, and destruction of the interior and channel torpedoes."

The principal reason for the exaggeration of the power of submarine attack is the absence of suitable experiment and wide experience. Inquiries into the organization of our torpedo service will show that only a limited number of officers have had any experience with torpedoes, and the statements of inventors and manufacturers have been relied on almost entirely as to their efficiency, because comprehensive experiments have not been made with the various types under the different conditions that are liable to occur in action. In fact, our authorities are still in the dark as to what can actually be done with automobile torpedoes; and although the genius of our torpedo officers has been brought to bear upon the old ship to doom her to destruction, her name was well bestowed, and the Resistance still floats, a testimony of the fallibility of the torpedo or the want of *savoir faire* in experiment.—*Engineering.*

SIBLEY COLLEGE LECTURES.—1886-87.

BY THE CORNELL UNIVERSITY NON-RESIDENT LECTURERS IN MECHANICAL ENGINEERING.

II.—A TEST OF STEAM BOILERS AT NASHVILLE, TENN.

By JOHN W. HILL, Cincinnati, O.

The firm of Warden & Mitchell, of Philadelphia, in a competitive letting, contracted with the Water Department of Nashville, Tenn., for a battery of five return tubular boilers, each of the following dimensions:

Diameter of shell	72½ in.
Length of shell	20 ft.
Number of tubes	38
Diameter of tubes (outside)	4 in.
Heating surface 1 boiler, shell	199.8 sq. ft.
Heating surface 1 boiler, tubes	795.87 "
Heating surface 1 boiler, heads (½ of net area)	24.96 "
Heating surface, total five boilers	5,163.15 "
Superheating surface, 1 boiler	129.6 "
Superheating surface, 5 boilers	648.0 "
Grate surface, 5 boilers	120.0 "
Ratio heating to grate surface	42.53
Cross section of tubes	13.63 sq. ft.
Ratio grate surface to cross section of tubes	9.12
Cross section of chimney	17.00 sq. ft.
Ratio grate surface to cross section of chimney	6.46

These boilers are set in independent furnaces, with independent smoke, steam, and feed water connections.

Over each boiler an arch is sprung, through which the products of combustion pass from front to back to the smoke connection leading to the base of the chimney.

The chimney which furnishes the draught for these boilers is a peculiar affair. Although of a height of 137 feet above the grates, but 70 feet of this is vertical; the remainder, less 28 feet vertical elevation of base of chimney above grates, is included in a sloping flue, which leads from the rear of the boilers to the vertical portion of the chimney, perched upon a hill above the boiler house.

The pumping house of the water works at Nashville is located above the city, on the left bank of the Cumberland River, and the site is a ledge cut in the rocky bank above flood tide. Back of the pump house the natural rocks tower above the buildings, and upon the summit of these the vertical shaft of the chimney is located.

The shaft and flue leading to it had previously been used with a battery of boilers displaced by the new tubular boilers.

There was nothing remarkable about these boilers excepting, perhaps, the contract under which they were furnished, which among other conditions, contained a guarantee that, during 72 hours of the contract trial, they should show an evaporation of 10½ pounds of saturated steam per pound of combustible, while making steam at the rate of 18,000 pounds per hour, from a temperature of feed water of 125 degrees Fahr. and under a pressure by gauge of 80 pounds, with a brand of bituminous coal known in the Nashville market as "Hecla" coal.

It is needless to tell you that an evaporation of 10½

pounds of saturated steam per pound of combustible from a feed water of 125° Fahr., and at a pressure of 80 pounds by gauge, is not often obtained with any bituminous coal; and with a coal much inferior to what is known as Pittsburgh or Youghiogheny, Kanawha, W. Va., Cumberland, Massillon, and many other soft coals of Northeastern Ohio, Eastern Kentucky, and West Virginia, it is, in my judgment, an impossible economy, excepting under extraordinary conditions; and while there were some extraordinary conditions at Nashville, these were of a character to impair, rather than enhance, the economical efficiency of the boilers.

One of these I have already alluded to as the chimney, the principal portion of which lay along the ground, and another was the ratio of grate surface to cross section of tubes and chimney.

Good practice has established the ratio of grate surface to cross section of tubes as 5 to 7.5, and the ratio of grate surface to cross section of chimney (for chimney of 80 to 125 feet in height) as 4 to 6.

In this case, the ratio of grate surface to cross section of tubes is 9.12, and of grate to chimney is 6.46, and it will appear in discussing the results of the contract trial that these two defects are clearly noticeable in the economical work of the boilers.

The contract requirement of 18,000 pounds of steam per hour represented an evaporation per square foot of heating surface per hour of 3.527 pounds of steam, which good practice would indicate as a rate of evaporation too high for best results; and this weight of water evaporated at 80 pounds pressure from a temperature of 125° Fahr. is equivalent to the transfer of 18,000 × (1212.47-125.275) = 19,569,510 heat units per hour from the fuel burned on the grate to the water fed into the boilers.

This large evaporation to be accomplished for at least 12 of the 72 hours of trial provided for test purposes by the contract under which the boilers were furnished.

Previous to my visit to Nashville to conduct this trial, I had no knowledge of "Hecla" coal, but I had had considerable experience with the modern forms of steam boilers, and with many varieties of anthracite and bituminous coals, and I realized the improbability of obtaining the contract economy, excepting under very favorable circumstances, and with a fuel as fully developed as Pittsburgh, Cumberland, and some of the Kanawha coals.

One of the unfavorable conditions, apart from the quality of the coal, which, in my judgment, was calculated to defeat the required economy, was the rate of evaporation at which the boilers must be worked.

My own experience, and that of others, with tubular boilers seems to demonstrate conclusively that high economy cannot be had with high rates of evaporation, but rather at ratios of 1 to 2 pounds of steam per square foot of heating surface per hour, while the contract requirements in this instance were in excess of 3.5 pounds per hour.

This, with the peculiar construction of the chimney, and the high ratio of grate surface to flue vent and area of chimney, seemed to prohibit the attainment of the contract economy.

All other conditions favoring it would require a first-class bituminous coal to obtain an evaporation of 10½ pounds of steam per pound of combustible.

"Hecla" coal, although fair and burning to good advantage, as appears from an examination of the results of the trial, is not a fully developed bituminous coal, as is clearly shown upon fracture by the *lignite* condition of the broken surface.

The service in which the boilers are worked is such that they are required to furnish the steam consumed in operating the four two and a half million gallon pumping engines at this station; and as these engines are of the compound non-condensing Worthington type, this consumption is bound to be relatively large.

The rate at which these pumps were operated to maintain the city supply of water compelled the working of the boilers fully up to the contract requirements for capacity.

It was the intention to experiment with the coal and plant previous to entering upon the 72 hours of contract trial, to determine under which mode of firing and area of grate the best results might be had from the fuel. But the limited time which I was free to devote to this investigation prevented any preliminary experiment, and the test was made with no information which might be used as a guide to best conditions for economy. Previous to the test, however, the grate surface, at a venture, was reduced from 30 to 24 square feet to each boiler, and so used during the trial.

The requirements of the contract (so far as it directed) were observed in making the trial.

The trial beginning at 12:25 P. M., February 25, and continuing without interruption to 12:25 P. M., February 28, as regards the coal consumed; and from 1 P. M., February 25, to 1 P. M., February 28, as regards the water supplied to the boilers.

The methods of measurement and observation were as follows:

The coal was weighed on an acceptable scale in the boiler house in uniform charges of 400 pounds each, 5 charges (1 to each boiler) at a round, as required, one charge only at a time being allowed on the floor before each furnace.

As soon as these several charges were exhausted, a new round of 5 charges of 400 pounds each, or 2,000 pounds in all, was weighed up, and by the observer entered as at the time of weighing; and dumped on the floor before the respective boilers.

During the trial, there was weighed up and charged to the test 425 scale draughts, or 400 × 425 = 170,000 pounds of coal.

Of this, at various times during the 72 hours, small quantities of refuse coal were culled from the charges after weighing, and thrown into barrels provided for the purpose. These quantities were always weighed back by the assistant in charge of the coal at the time of changing the watch, with an entry in his note book of the date, time, and quantity returned, as follows:

February 25, 6:25 P. M.	164 pounds.
" 26, 6:15 "	200 "
" 27, 6:11 "	162 "
" 28, 12:25 "	28 "

Total..... 554 pounds.

At the end of the trial, after the fires were restored to

their original condition, there was returned and weighed 431 pounds from the last round of coal charged, making a total subtraction from gross weight of coal of 985 pounds, and a net consumption of 169,015 pounds.

Dividing this by interpolation of the record into the quantities burned for each 12 hours of trial, we have the following table:

Coal Record.

Periods.	Total coal consumed.	Rate per hour.	Coal per sq. foot of grate per hour.
1st 12 hours.....	29,169.33	2,430.78	20.25
2d ".....	28,779.88	2,398.32	19.99
3d ".....	29,175.16	2,431.26	20.26
4th ".....	27,238.90	2,269.91	18.91
5th ".....	27,474.36	2,289.53	19.08
6th ".....	27,177.37	2,264.78	18.87
Average.....		2,347.43	19.56

During the trial the fires were partially drawn at different times, and the ash, clinker, and refuse from the ash pits weighed up dry, with the following results:

February 25, 6:25 P. M. by Mr. Mullen.....	1,259.0 lb.
" 26, 6:40 A. M. " Wallman.....	2,009.5 "
" 26, 2:56 P. M. " Mullen.....	925.0 "
" 26, 6:58 P. M. " ".....	906.0 "
" 27, 12:36 A. M. " Wallman.....	988.0 "
" 27, 7:35 A. M. " Mullen.....	1,322.0 "
" 27, 10:15 A. M. " ".....	268.0 "
" 27, 5:24 P. M. " ".....	1,076.0 "
" 27, 7:40 P. M. " Wallman.....	562.0 "
" 28, 1:10 A. M. " ".....	2,547.0 "
" 28, 7:30 A. M. " Mullen.....	745.0 "
" 28, 12:25 P. M. " ".....	3,613.0 "

Total ash and clinker..... 16,220.5 lb.

And the percentage of combustible in the coal was:

$$100 \left(1 - \frac{16,220.5}{169,015} \right) = 90.4;$$

showing 9.6 per cent of ash, clinker, and loss in the coal as burned.

The arrangement for measuring the feed water consisted of two large wooden tanks, one of which was elevated above the floor of the engine room upon a pair of "horses," into which water from the mains was drawn to an overflow notch cut in the side of the tank, and the other placed below and to one side of the measuring tank, with a connection to the suction of the boiler feed pump.

The suction tank was furnished with a gauge point to indicate the level of water in it upon starting, and to this gauge point the water was returned at the end of the trial.

The measuring tank was always filled to the overflow notch, and after the surface of water was quiet and smooth, the entire contents of the tank were drawn off as required into the suction tank below.

From the suction tank the feed water was pumped through a closed heater, which received the exhaust from the principal pumping engines, where it was warmed before passing into the boilers.

Previous to the trial these tanks were leaking badly, and, to avoid too much delay, recourse was had to a measurement of the water supplied to the boilers by the motion of the "Knowles" feed pump.

This pump under normal conditions takes water at a pressure of 58 pounds from the force main leading from the pumping station to the city, and upon measurement was found to be of the following dimensions:

Diameter of water cylinder..... 4.375 inches.

" of piston rod..... 1.125 "

Stroke..... 9.25 "

This pump had been examined and put in good working order shortly before the trial, and taking its suction under pressure made full strokes, from which was deduced the discharge per double stroke, with an allowance of 2 per cent. for loss of action, and estimate of 8.34 pounds per gallon of water at 45 degrees Fahr. as 9.515 pounds, nearly.

The water was measured by the pump displacement from 1 P. M., February 25, to 12:20 P. M., February 26, during which interval of time the measuring and suction tanks had been overhauled and put in proper condition for service.

The average of double strokes per minute for the first 23 hours and 2 minutes of trial was 34.56, corresponding to a pump displacement of 455,645.7 pounds of water.

For the remainder of the trial the water was tanked to the boilers at the rate of 4,044 pounds to the tank (the capacity of the tank having been tested with water at 45 degrees Fahr. by filling and weighing out several charges).

From 12:02 P. M., February 26, to 1 P. M., February 28, 23½ tanks were measured and the water pumped into the boilers, representing a delivery of 904,508 pounds, which, added to the quantity estimated from the pump displacement, made the total delivery of water to the boilers for the 72 hours of trial, 1,360,153.7 pounds.

From this was drawn during the first 29½ hours of trial 425.15 pounds for test of temperature of feed water, leaving 1,359,728.6 pounds of water actually pumped into the boilers.

Dividing, by interpolation of the water record, the water pumped to the boilers for whole trial into six quantities corresponding to the six equal intervals of 12 hours each, we have the following results:

From 1 P. M., February 25, to 1 A. M., February 26: By pump measurement, average double strokes per minute—from 15 minute records of speed—34.875; and estimated weight of water discharged by the pump for 12 hours, 238,915.4 pounds.

Less amount drawn from cock in feed pipe, caught and weighed for 12 hours, 172.94 pounds; and net water delivered to boilers, 238,742.4 pounds.

For the second 12 hours, from 1 A. M., February 26, to 1 P. M., same date, the average double strokes of pump per minute was 34.41, corresponding to a displacement of 216,727.62 pounds of water for 11 hours

* "Torpedoes for National Defense." By Lieutenant W. H. Jaques, U. S. Navy, 1886. J. P. Putnam's Sons, London.

and 3 minutes; and by tank for a period of 58 minutes, 13,657.4 pounds.

From which is subtracted the quantity of water drawn from cock in feed pipe, caught and weighed for 12 hours, 173.94 pounds, leaving net water delivered to boilers as 230,242.07 pounds.

For the third 12 hours, from 1 P.M., February 26, to 1 A.M., February 27, the quantity of water by tanks delivered to the feed pump was 230,974.6 pounds. From which is subtracted the water drawn from cock in feed pipe, caught and weighed for 5 hours and 30 minutes, 79.27 pounds, leaving net water pumped to boilers 230,895.33 pounds.

For the fourth 12 hours, from 1 A.M., February 27, to 1 P.M., same date, the quantity of water tanked to the feed pump was 232,083 pounds. This was also the net quantity delivered to the boilers, the water drawn from the cock in feed pipe being caught and returned to the suction tank.

For the fifth 12 hours, from 1 P.M., February 27, to 1 A.M., February 28, the quantity of water tanked to the feed pump was 219,783.47 pounds. This was the net quantity to boilers, as in the previous interval, the water drawn from the cock in the feed pipe having been caught and returned to the suction tank.

For the last 12 hours of the trial, the quantity of water delivered to the boilers by tank measurement was 217,979.53 pounds.

During the 72 hours of trial the steam pressures were read from two gauges, and the temperature of feed water taken at the check valves near the boilers, regularly every 30 minutes.

The temperatures of air outside and inside the boiler house were read hourly; and the temperatures of the hot gas in the smoke head, in the flue leading to the chimney, and at the base of the vertical section of the stack were taken every hour, with the following averages for whole trial:

Steam pressure, gauge No. 1, as read...	70.8 pounds.
" " " " corrected.	68.27 "
" " " " No. 2, as read...	70.02 "
" " " " corrected.	68.49 "
Temperature of air outside boiler house	36.53 Fahr.
" " " " inside	47.81 "
" " " " hot gas in smoke head...	467.41 "
" " " " in entrance to brick flue.....	427.88 "
Temperature hot gas at base of chimney.....	396.96 "
Temperature of water from force main to boiler feed pump and to measuring tanks.....	44.74 "
Temperature of feed water to boilers as read.....	203.14 "
Temperature of feed water corrected for specific heat.....	204.825 "

The average apparent evaporation per pound of coal from temperature of feed water for the 72 hours of trial was:

$$\frac{1,359,728.56}{109,015} = 8.045 \text{ pounds;}$$

and per pound of combustible:

$$\frac{8.045}{0.904} = 8.9 \text{ pounds.}$$

The average apparent evaporations for the several intervals of 12 hours were, per pound of coal:

First 12 hours,	$\frac{238,742.4}{29,169.33} = 8.185 \text{ pounds.}$
Second 12 hours,	$\frac{230,242.07}{28,779.87} = 8.00 \text{ pounds.}$
Third 12 hours,	$\frac{230,895.33}{29,175.16} = 7.91 \text{ pounds.}$
Fourth 12 hours,	$\frac{222,083}{27,238.9} = 8.15 \text{ pounds.}$
Fifth 12 hours,	$\frac{219,783.47}{27,474.36} = 8.00 \text{ pounds.}$
Sixth 12 hours,	$\frac{217,979.53}{27,177.37} = 8.02 \text{ pounds.}$

And per pound of combustible for the several intervals respectively, the evaporations were:

1.	$\frac{8.1847}{0.904} = 9.05 \text{ pounds.}$
2.	$\frac{8.0001}{0.904} = 8.85 \text{ pounds.}$
3.	$\frac{7.9141}{0.904} = 8.75 \text{ pounds.}$
4.	$\frac{8.1531}{0.904} = 9.02 \text{ pounds.}$
5.	$\frac{7.993}{0.904} = 8.85 \text{ pounds.}$
6.	$\frac{8.0206}{0.904} = 8.87 \text{ pounds.}$

The calorimeter data were taken hourly, with a very satisfactory apparatus; the scale upon which were taken the weights of condensing water and condensed steam being furnished with a smooth beam and sliding poise, and capable of being read to eighths of a pound. Moreover, the scale was very sensitive to slight changes of weight.

The temperatures were taken with a James Green U. S. Signal Service thermometer.

During the 72 hours of trial, 70 observations were made, with the following average results:

Weight of condensing water.....	200 pounds.
Weight of steam condensed.....	13.54 "
Initial temperature condensing water as read.....	48.05° Fahr.
Initial temperature corrected for specific heat.....	48.058 "
Final temperature of condensing water as read.....	122.061 "
Final temperature corrected for specific heat.....	122.321 "
Thermal units found, per pound of steam.....	1219.26
Thermal units per pound of steam at observed pressure.....	1200.82
Degrees of super heat.....	19.88
Efficiency of the steam (saturated steam 1000).....	1007.85

The means of the calorimeter data, for the several intervals of 12 hours each, are given in the following table:

Interval, 12 hours.	Condensing Water.	Steam Condensed.	Initial Temp.	Final Temp.
First.....	200	14.0164	50.196	126.285
Second.....	200	13.1562	47.333	119.437
Third.....	200	13.5625	47.396	121.593
Fourth.....	200	13.7125	47.100	121.975
Fifth.....	200	13.4259	47.432	121.091
Sixth.....	200	13.2868	48.341	121.136

Interval, 12 hours.	Corrected Initial Temp.	Corrected Final Temp.	Range.	Heat units per pound of steam.
First.....	50.198	126.582	76.384	1216.536
Second.....	47.834	119.675	72.341	1219.416
Third.....	47.897	121.818	74.421	1219.311
Fourth.....	47.101	122.233	75.132	1218.093
Fifth.....	47.433	121.342	73.909	1222.333
Sixth.....	48.342	121.388	73.046	1220.918

Showing degrees of super heat as follows:

14.14 for first 12 hours.
20.20 " second " "
20.00 " third " "
17.63 " fourth " "
26.30 " fifth " "
23.36 " sixth " "

The temperature of feed water corrected for specific heat for whole trial has been stated as 204.82° Fahr., and for the several intervals of 12 hours into which the trial has been divided was, for:

First 12 hours	203.3 observed.	205.0 corrected.
Second " "	203.87 "	205.6 "
Third " "	203.72 "	205.4 "
Fourth " "	203.48 "	205.2 "
Fifth " "	202.13 "	203.8 "
Sixth " "	202.27 "	203.9 "

From which we derive the evaporation per pound of combustible from and at 212° Fahr. as required by the contract, for the entire trial, as:

$$\frac{1219.63 - 204.83 \times 8.9}{965.7} = 9.35 \text{ pounds.}$$

Or more than one pound below the contractor's guaranteed economy.

For the several intervals of the trial, the economy in steam per pound of combustible from and at 212° Fahr. based upon the coal and water, temperatures of feed water, and condition of the steam for that interval, was as follows:

For the first 12 hours of trial:	$\frac{1219.536 - 204.99 \times 9.0535}{965.7} = 9.48 \text{ pounds.}$
For the second 12 hours of trial:	$\frac{1219.416 - 205.42 \times 8.849}{965.7} = 9.29 \text{ pounds.}$
For the third 12 hours of trial:	$\frac{1219.311 - 205.42 \times 8.754}{965.7} = 9.19 \text{ pounds.}$
For the fourth 12 hours of trial:	$\frac{1218.093 - 205.18 \times 9.018}{965.7} = 9.46 \text{ pounds.}$
For the fifth 12 hours of trial:	$\frac{1222.333 - 203.82 \times 8.85}{965.7} = 9.33 \text{ pounds.}$
And for the last 12 hours of trial:	$\frac{1220.918 - 203.96 \times 8.872}{965.7} = 9.34 \text{ pounds.}$

The greatest capacity of boilers was developed during the first 12 hours of trial, when water was supplied at the rate of 19.895.2 pounds per hour, corresponding to a transfer of 20,124,912 heat units from the fuel burned on the grate to the water pumped to the boilers, and equivalent to an evaporation from a temperature of 125° Fahr. to steam at 80 pounds pressure by gauge, of 18,510.86 pounds, or over 500 pounds in excess of the contractor's guaranteed capacity.

An examination of the table of economy shows but little variation from interval to interval, and that the difference of nearly 10 per cent. in the quantity of water supplied to the boilers, and the rate of evaporation per superficial foot of heating surface between the first and last 12 hours, had very little effect upon the evaporation per unit of fuel, and the slight variation shown was due to the cleaner condition of the boiler

tubes and furnaces rather than to the higher rate of evaporation for the earlier period.

Considering the quality of the coal, the improper proportions of grate surface, tube vent, and area of chimney, and the length of brick flue for given height of the chimney, I regarded the economy as excellent.

From several tests of the rate of flow of the hot gas through the flues, it was found to vary between 10.86 and 17.86 feet per second, corresponding to a discharge of 1,056,312 cubic feet of hot gas per hour, at an average temperature, from surface of grate to top of chimney, of 731.84 degrees Fahr., equivalent to an introduction into the furnaces of

$$\frac{1,056,312 \times 493.2}{731.84 + 461.2} = 496,670 \text{ cubic feet of air at}$$

normal temperature (34° Fahr.).

The coal was burned at the rate of 2347.43 pounds per hour for whole trial, and for proper combustion should be supplied with 314 cubic feet of air (at normal temperature) per pound, corresponding to 737,093 cubic feet of air per hour, while, in fact, the chimney is capable of furnishing by natural draught only 59 per cent. of the required quantity.

While there is room for argument upon the effect of the tube vent, area of chimney, and rate of evaporation upon the economical performance of the boilers, there can be none on the quality of the coal. This, while good of its kind, was not of the kind with which high economy can be had.

An evaporation of 10½ pounds of steam per pound of combustible is not an unusual result, with well proportioned tubular boilers, well set, and connected with a chimney of proper dimensions, when fired with a first-class coal; but these boilers are in some respects not well proportioned, the setting not what best practice would recommend, and the dimensions and arrangement of chimney are positively faulty.

I did not regard the failure of these boilers to comply with the economy terms of the contract under which they were built as reflecting upon the contractors or the water works officers at Nashville; but rather as one of those unfortunate mistakes which is liable to occur, where the quality of the fuel and the efficiency of existing appurtenances is assumed, instead of being measured by some reasonably reliable method.

In the body of the paper, I have given the results of the calorimeter data for the whole trial as an average of all the experiments, and for the several intervals of 12 hours each. I now desire to analyze these data a little more, and make some inquiry into the reliability of tests for quality of steam, as these were made at Nashville.

In making tests for the quality of steam with the primitive apparatus described, great care is necessary to avoid serious errors and misleading results.

The general precautions to be observed are: That the steam pipes through which the samples are drawn shall be blown clear of any condensation which may have accumulated during the interval between observations (to reduce this condensation to a minimum, the steam pipe should be covered with hair felt or canvas wrapped with twine from the steam drum or dome down to the stop valve which controls the flow).

That the flow shall be through an unobstructed passage in the stop valve (this requires a plain stop cock or a properly constructed gate valve, arranged to withdraw the plug or wedge entirely clear of the passage).

That the weights of condensing water and condensed steam be taken quickly and accurately, and that the temperatures of the condensing water, before and after the steam is blown in, be noted as closely as possible with the thermometer in use.

In addition to the condensation in the steam pipe, above the regulating valve, there is always a slight condensation in the pipe between the valve and the surface of the water in the tub, which should be blown out and the pipe warmed, by making the initial weight of condensing water a pound or a half pound less than the arbitrary weight taken for the standard. Thus, if the standard is taken at 200 pounds, the initial weight may be 199 or 199.5 pounds, the remainder being obtained from the steam blown out to clear the lower portion of the pipe.

It is but fair to state that the method of testing the quality of steam for the Nashville trials is condemned by many excellent engineers. Among others by my recently deceased friend, Mr. J. C. Hoadley, of Boston, who refused to compute water entrained from data taken in this manner, and in fact just before his retirement from professional work seemed to have had little faith in any of the processes heretofore employed.

With due respect for the opinions of those who desire to make tests for quality of steam in some other manner, or not to make these tests at all, upon the theory that no correct method has yet been devised, I must incline to the belief that the primitive apparatus first employed in this country by your distinguished preceptor (Prof. Thurston) is not only the best for the purpose, but is calculated, with correct scales and thermometers, and due care in the taking of the data, to furnish tolerably reliable results; and I arrive at this conclusion only after repeated experiments with this and several other forms of apparatus, including the coil or continuous calorimeter.

That there are some crudities in the method, and necessary discrepancies in the results, cannot be disputed, but these are not (in my opinion) of such a character as to preclude tolerably accurate results, when the apparatus is in proper condition and due care is observed in taking the data.

The scale employed for calorimeter purposes in the Nashville tests was a new one never before used, with a capacity of 400 pounds. The beam was graduated to quarter pounds and furnished with a sliding "P" and index, enabling weights to be readily taken as close as two ounces. Tests at intervals showed the scale beam to turn promptly upon an ounce, and I conceive the greatest error of weight must have been less than this quantity. Assume it an ounce, however; the average weight of steam condensed was 13.5 pounds, or 216 ounces, and the probable error of weight less than one-half (0.463) per cent. With an assumed possible error in taking the weights of steam condensed of two ounces, the percentage of error would have been less than one per cent. But the scale beam was easily read to eighths

o a pound, and the actual error must have been less than two ounces, or considerably under one per cent. of the average weights of steam condensed.

The next source of error is in reading the thermometer. The instrument used for this was graduated to degrees, with divisions of about $\frac{1}{16}$ inch. The thermometer was read to the nearest full or half degree, and these data may have been in error one-quarter degree.

The average range of temperature for the 79 hours of trial was 74 degrees, and an error in reading the temperature of one-quarter degree would affect the range $\frac{0.25}{74} \times 100 = 0.34$ per cent.; and an error of one-half degree (which I do not regard as possible with the instrument in use) would affect the range of temperature less than 0.7 of one per cent.

In reading thermometers or other graduated instruments, there is a personal error, which consists, according to the peculiarity of the observer, of over or under reading; but, as the first and second temperatures were read by the same observer, this class of error should be of no effect in considering the accuracy of the method employed or of the results obtained.

In allowing for the capillarity of the mercury in the tube of the thermometer, with diminishing and increasing temperatures, it should be observed that the top of the column will be concave on its descent and convex in its ascent, and the height of the column should be taken as the apex or base of the curve, according to the downward or upward movement of the mercury.

In calorimeter readings of thermometers where the fluctuations of temperature are rapid, the effect of capillary attraction is very noticeable, and with a little care can be eliminated from the necessary errors of reading.

Another, and, I think, the most likely source of error, is in difference of temperatures in different parts of the tub after the charge of condensed steam has been blown in; to meet which, Mr. Hoadley employed, in some tests made at the Brush Electric Light Station, Philadelphia, several years ago, an agitator to distribute the heat and equalize the temperature of the mixture, allowance being made for the heat imparted to the water by the work expended in moving the agitator. This is a refinement in calorimeter tests which I have never reached, and I am not aware that Mr. Hoadley ever repeated his Philadelphia experience.

Some agitation of the water is necessary to equalize the temperature, and the thermometer should be carefully watched during this operation to mark the true maximum temperature. But it requires 772 foot pounds of work to produce a British thermal unit, or, rather, one thermal unit equals 772 foot pounds of work; while the entire operation of stirring the contents of the tub and taking a final thermometer reading is accomplished in about a half minute, and the quantity of work required to add one per cent. to the heat of the contents of the tub would be 617.6 foot pounds, or an average effect of more than twenty foot pounds per second.

According to the table found on page 636 of Rankine's Applied Mechanics (edition of 1872), the average work of a man shoveling earth to a height of 5 feet 3 inches is 7.8 foot pounds per second; wheeling earth in a barrow up a slope of 1 in 12 and returning with empty barrow, 10 foot pounds per second; pulling an oar, 53 foot pounds per second; working a pump, 10 foot pounds per second; turning a winch or crank, from 45 to 62.5 foot pounds per second; carrying weights up stairs, 18.5 foot pounds per second.

But all work of the character noted by Rankine is many times more laborious than that of stirring the contents of a calorimeter tub with a small paddle or with the metal back of the thermometer itself, and it is, not likely that an average effect equal to 20 foot pounds per second is expended in the work of agitation and distribution of the heat throughout the mass.

I have never made any experiments to determine the probable amount of heat added by the efforts usually made to equalize the temperature of the contents of the tub; but I do not think it sufficient to have any appreciable effect on the final results.

The error due to the agitation is, of course, a *plus* quantity, and is calculated to balance more or less the heat absorbed by the walls of the tub, by the iron of the calorimeter pipe extending into the tub, and the heat lost by insensible vaporization from the surface of the water and that lost by contact of air—all of which are *minus* quantities.

I have never attempted to reduce these losses to mathematical quantities, but I suspect that when that reduction is made, it will be found that the losses of heat are greater than the gains, and that the quantities of heat accounted for by this form of calorimeter are always less than the true heat of the steam.

During the Nashville experiments 70 tests for quality of steam were made, of which 39 were made by myself and 41 by assistant, Mr. Anderson. I am quite sure my assistant's observations were carefully made, and mine were made as closely as the nature of the apparatus would permit. Grouping the results of Mr. Anderson's observations and those made by myself, we have the following results:

	Hill.	Anderson.
Water heated, pounds.....	200	200
Steam condensed,	13'437	13'613
Initial temperature observed, ..	48'64	47'05
" corrected		
for specific heat	48'641	47'651
Final temperature observed, ..	122'086	122'048
" corrected		
for specific heat	122'346	122'302
Range of temperature	73'703	74'642
Total thermal value of the steam.....	1219'39	1219'062
Super heat.....	20 15 degs.	19'5 degs.

Grouping the experiments again upon the weights of steam condensed, we have 24 series as follows:

Series	1....1 observation with	9-125 pounds of steam.
"	2....2	" 13-000
"	3....3	" 12-500
"	4....4	" 12-50
"	5....5	" 12-625
"	6....6	" 13-75
"	7....10	" 12-875

Series 8....8 observations with 13-000 pounds of steam.

"	9....8	" 13-125	"
"	10....2	" 13-25	"
"	11....1	" 13-50	"
"	12....3	" 13-625	"
"	13....6	" 13-75	"
"	14....4	" 13-875	"
"	15....6	" 14-00	"
"	16....1	" 14-125	"
"	17....1	" 14-25	"
"	18....2	" 14-375	"
"	19....1	" 14-50	"
"	20....4	" 14-625	"
"	21....2	" 14-75	"
"	22....3	" 14-875	"
"	23....3	" 15-00	"
"	24....1	" 15-375	"

70 observations.

The initial and final temperatures as read and corrected for specific heat, and the ranges, are given in the following table:

Series.	Initial Temp.	Corrected.	Final Temp.	Corrected.	Range.
1	48'5	48'501	99'75	99'863	51'362
2	46'5	46'501	113'00	113'190	66'689
3	49'5	49'502	117'875	118'009	68'597
4	49'25	49'253	118'000	118'226	68'974
5	46'5	46'501	116'5	116'715	70'214
6	48'42	48'421	118'75	118'982	70'561
7	48'0	48'001	118'5	118'731	70'73
8	47'66	47'661	118'66	118'892	71'231
9	47'33	47'331	119'00	119'234	71'903
10	47'00	47'001	119'75	119'989	72'988
11	47'00	47'001	121'00	121'250	74'249
12	47'5	47'501	122'50	122'763	75'262
13	47'83	47'831	123'92	123'186	75'355
14	47'375	47'376	123'5	123'771	76'395
15	47'66	47'661	123'92	124'195	76'534
16	48'5	48'501	126'00	126'298	77'792
17	47'0	47'001	124'25	124'528	77'527
18	52'25	52'256	130'25	130'584	78'328
19	50'00	50'003	128'5	128'817	78'814
20	48'062	48'063	128'0	128'312	79'709
21	46'75	46'751	126'75	127'051	80'300
22	47'33	47'331	127'66	127'969	81'218
23	50'33	50'332	131'83	132'180	81'848
24	48'50	48'501	131'00	131'342	82'841

In the first column are the serial numbers corresponding to the weights of steam just read; in the second column, the initial temperatures as read; in the third column, the corrected initial temperatures; in the fourth column, the final temperature as read; in the fifth column, the corrected final temperatures; and in the sixth column, the true range of temperature of the contents of the tub.

When more than one draught of any given weight of steam was made, the average of the temperatures is given.

Calculating the total heat and quality of the steam from the data given in the table, we have for the 24 series the following results:

Series.	Weight of Steam condensed, Pounds.	Heat Units per Pound of Steam.	Super Heat Degrees Fahr.
1	9-125	1,225'60	33'23
2	12-000	1,224'67	31'26
3	12-500	1,235'65	12'27
4	12-56	1,216'53	14'15
5	12-625	1,229'01	40'41
6	12-75	1,225'82	33'70
7	12-875	1,217'45	16'06
8	13-00	1,214'75	10'38
9	13-125	1,214'89	10'68
10	13-25	1,221'09	25'0
11	13-50	1,221'23	24'02
12	13-625	1,227'52	37'27
13	13-75	1,219'25	19'87
14	13-875	1,224'96	31'87
15	14-00	1,217'53	16'24
16	14-125	1,227'77	37'80
17	14-25	1,212'63	5'91
18	14-375	1,220'36	22'20
19	14-50	1,215'90	12'81
20	14-625	1,218'35	17'96
21	14-75	1,215'86	12'72
22	14-875	1,229'23	40'86
23	15-00	1,223'49	28'78
24	15-375	1,309'00	60'60

In determining the condition of the steam in the table, I have assumed a uniform boiler pressure equivalent to the mean pressure for the 72 hours of the trial; and as the record shows a maximum variation in the steam pressure of but 4 pounds for the whole time, no serious error can arise from taking a uniform pressure for the entire series of calorimeter observations.

The quantity of condensing water was uniformly 200 pounds, while the weights of steam condensed varied from 9 $\frac{1}{8}$ to 15 $\frac{3}{8}$ pounds, and was weighed as found in the tub after the steam valve was closed. Hence the frequency of fractional weights.

The heat units per pound of steam are found by multiplying any range of temperature in the table by the ratio of the condensing water to the weight of steam condensed, to the product of which is added the corrected final temperature. Should this quantity be in excess of the heat of saturation at the given pressure, then the difference of heat units divided by decimal 0.475 gives the degrees of super heat on the Fahrenheit scale. By reference to the last table, it is seen that the condition of the steam ranged from saturation to nearly 41 degrees super heat, which, in view of the range of temperature of the hot gas flowing over the superheating surface, is not an unreasonable or unlikely variation.

The maximum range in the condition of the steam, from these 70 experiments, made hourly during a continuous trial of three days, without interruption or change of the general regimen of the boilers and furnaces, or in the rate of consumption of steam, or in

the steam pressure at which the boilers were worked, is comprehended within 19 thermal units, or about 1 $\frac{1}{2}$ per cent. of the total heat of the steam; or if the 24th experiment in the list is omitted, then the variation of condition is embraced in a range of 16.6 thermal units, equivalent to 1 $\frac{1}{4}$ per cent. of the total heat of the steam. The twenty-fourth experiment was one of the number made by myself, but there is no remark in my notebook to indicate an objection to it, but it is possible that an error of reading the scale beam or the thermometer is the cause of this divergence from the other 69 results.

It is, however, given for what it is worth.

With the exception of this single observation, the variations in the amount of super heat are only what we must expect from the fluctuations of the temperatures of the hot gas passing through the flue over the boilers.

During the 72 hours of trial, this temperature ranged between the limits of 367 and 535 degrees Fahr., and the amount of super heat should be directly referable to the temperature of the hot gas on its way over the superheating surface of the shell to the base of the chimney.

An examination of the table last given shows that the quality of the steam is unaffected by the weights of steam drawn for test purposes, which would scarcely be the case if the method was faulty or the observations carelessly made.

It also appears that the independent work of separate observers produces no substantial variation in the results; and from the former table of results for the six intervals or periods of 12 hours each, that the quality of steam for different intervals of the trial varied no more than should be expected in boilers provided with superheating surface, and a widely varying temperature of hot gas impinging on that superheating surface.

Comparing the coil or continuous calorimeter with the tub and scale, the same objection to thermometer readings is found, with this difference: that in the coil apparatus three separate thermometers are necessary—one to take the temperature of the condensation from the coil; one to take the temperature of the condensing water as it flows into the tank surrounding the coil; and another to take the temperature of the overflow from the tank.

Those who have had experience with thermometers understand the difficulty of procuring several instruments which will agree for any reasonable range of temperature, and I think a method which admits of taking all the temperatures with one thermometer is to be preferred. For it is much easier to obtain one perfect instrument than to obtain several, as is shown in an anecdote related of a celebrated New York maker of thermometers, who, when he was called upon, several years ago, by a well known Boston engineer, to make a very accurate thermometer, with special graduations, insisted he was able to construct such an instrument as was required, but would be obliged to ask a very large price (about \$50) for it; whereupon the engineer told the maker to furnish him two such thermometers, and the thermometer maker somewhat "wiser than his day and generation," declined the order, upon the theory that while it was an easy matter to make one perfect thermometer, it was impossible to make a mate to it.

Another objection to the continuous calorimeter is the difficulty usually experienced in measuring accurately the weight of circulating water, owing to the large quantities usually consumed with this arrangement. If this can be tanked or weighed, no material error should occur; but if it is to be measured by the flow over a weir or through an orifice, many opportunities for error will arise, and if measured through a water meter, as is sometimes done, no reliance can be placed in the record at all.

With the intermittent apparatus, the weights of condensing water and condensed steam may be taken with great accuracy, and without risk of these factors being in error enough to materially affect the final results.

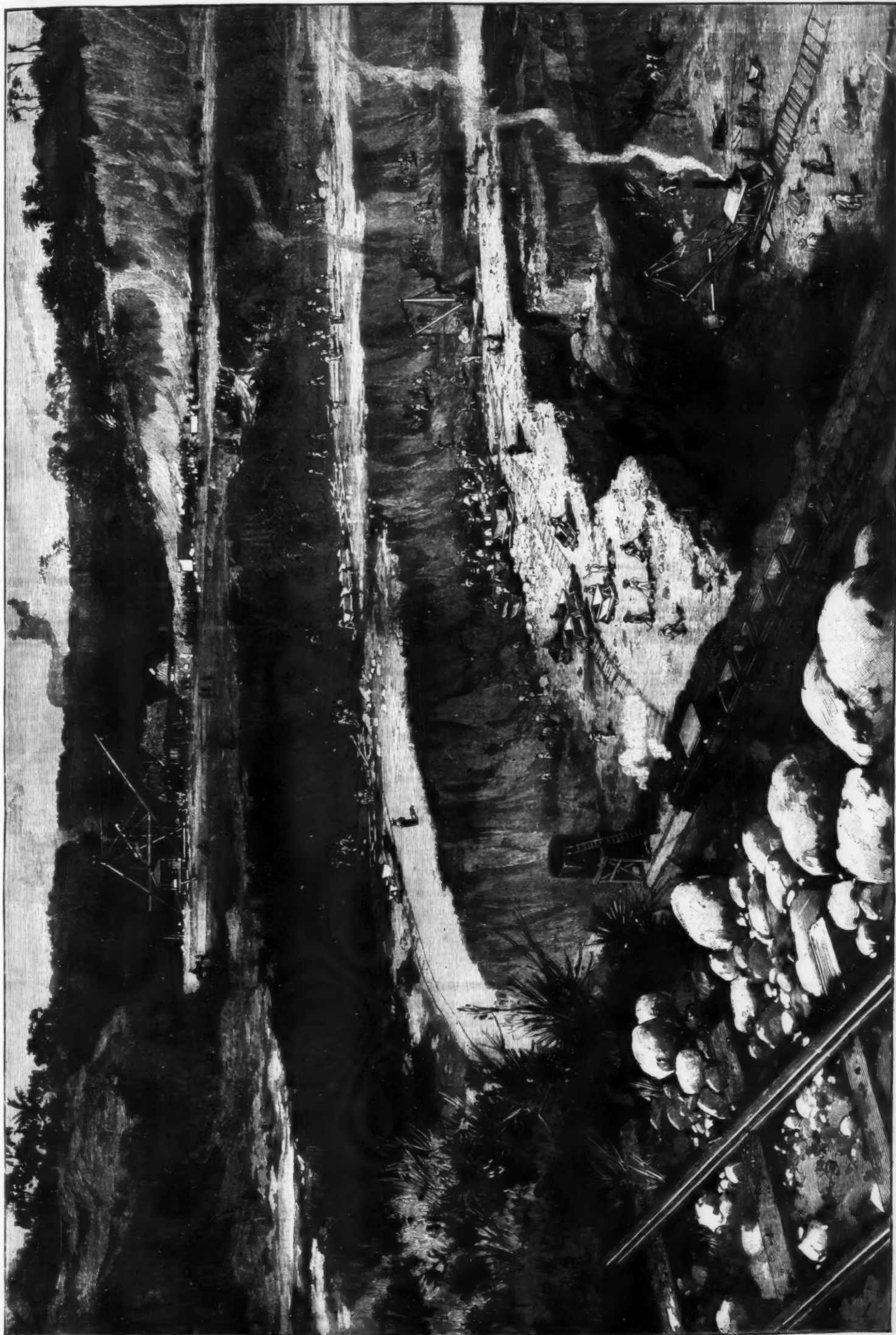
It is true that the coil calorimeter is working during all the time of a test, but the thermometer readings are not taken continuously, but at intervals, and there is no record of the fluctuations of temperature between two readings; and if the temperatures are to be taken intermittently, I can see no special benefit arising from a continuous record of steam condensed and water consumed in condensing it, excepting possibly the avoidance of error due the initial heat expended in warming the apparatus, which occurs but once in the continuous arrangement, and is repeated with every experiment in the intermittent apparatus.

This I think, however, is fully offset by the possible discrepancy in the weight of the circulating water, which (by the methods usually employed to measure it) may be in error several per cent.

THE GREAT COLIMA CUT, PANAMA CANAL.

From the engraving upon the opposite page, a just conception may be formed of the vast magnitude of this undertaking, particularly when we remember that this is but a small portion of many miles of similar work. In some parts the cutting is required to be over 400 feet deep. The picture also clearly illustrates the methods pursued. The heading is divided into steps, extending in a curved line across the cut, and upon each of which machinery and men are employed. The excavated material is placed upon cars, which are hauled back along the completed line to the dumping ground, which is, of course, so located that the wash of the heavy tropical rains will not carry the earth back into the canal.

The canal will extend from Colon on the Atlantic side to Panama on the Pacific, a distance of 46 miles; the average width at the bottom will be 75 feet, and the depth 20. It is to be a tidewater canal—no locks. The work is now being pushed forward at each end and at intermediate points along the line. The total amount excavated up to February last was 14,678,856 cubic meters, leaving 105,821,144 cubic meters yet to be removed. So far, more than \$100,000,000 have been expended, and although it is impossible to estimate the total cost with any degree of accuracy, it will certainly run above \$250,000,000, and will probably exceed \$300,000,000. In the SCIENTIFIC AMERICAN SUPPLEMENT, No. 564, is an illustrated article by C. D. Jameson, C.E., describing the work from its inception. In



THE PANAMA CANAL. THE GREAT COLIMA CUTTING.

other back numbers of the SUPPLEMENT various illustrations and descriptions will be found, the whole forming a complete running history of this gigantic undertaking.

INDUSTRIAL EXHIBITION, NEWCASTLE-UPON-TYNE, 1887.

WE publish a bird's eye view, lithographed by Mr. Andrew Reid from an original drawing prepared by the architect of the exhibition by which it is proposed to celebrate the Royal Jubilee in Newcastle next year.

The site on which the building will stand is that known as the Bull Park, and forming part of the Town Moor. It is within easy distance of the center of the city, being only about a mile from the Central Station, and about half a mile from the New Bridge station of the Blyth and Tyne section of the North-Eastern Railway; and it is readily accessible to visitors, trams passing along the North road every few minutes. The ground set apart for the building also extends about 150 ft. northward into the Recreation Ground, inclosing the ornamental waters, and the whole occupying an area exceeding 20 acres. From the plans prepared by the architect, Mr. Wm. Glover, Market Street, Newcastle, there is shown an entrance of classic design, constructed of wood, and having a frontage of 150 ft., with a portico 50 ft. in length, extending to the line of the curb. It is surmounted by a pediment with a clock and dome 64 ft. in height, and having two side turrets, each 70 ft. in height.

On the north side of the entrance are ranged the cashier's office, change office, post office, parcels stores, and ladies' cloak room. On the south side will be the general office, offices of the general superintendent, assistant superintendent, honorary secretary, and council room. The entrance lobby will be 50 ft. long by 40 ft. wide, opening into a large crush room of 150 ft. by 50 ft. This will form the entrance to the North Court, which will be carried out in three spans of 50 ft. in width, and lean-tos of 20 ft. in width. The height to the ridge of the roof, in the Central Court, will be 40 ft., and that of the two sides 35 ft.

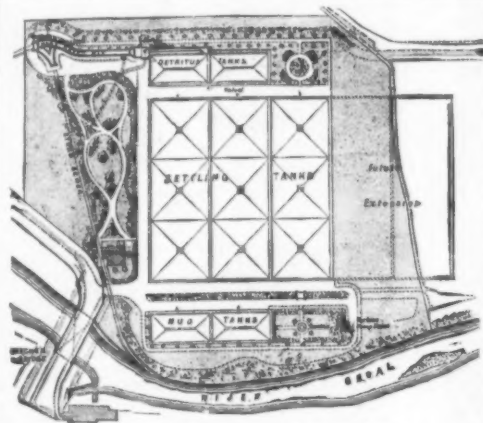
At the end of the North Court will be placed the organ and concert room, the center forming the avenue from the inclosed area to the mining exhibits. The Western Court, in which the machinery in motion will be situated, will have a central span of 50 ft. in width and 35 ft. in height, with two lean-tos possessing an average height of 18 ft. To the west of this court will be placed the boilers and electric lighting machinery. The South Court will be similarly constructed, and to the south of it will be ranged the art saloon, theater, dining rooms, canteen, and extensive kitchen. On the same principle, too, will be the East Court, which, however, is kept at a distance of 25 ft. from the east wall of the Bull Park, in order to avoid the destruction of the trees at that portion of the ground. In this department will be arranged exits and a lavatory. The total length of the North and South Courts will be 450 ft.; while the East and West Courts, which will form a junction with them, will be 346 ft. in length. The Courts are arranged so as to form a quadrangle of 346 ft. in length and 270 ft. in width. All round this area will be a veranda, extending 9 ft. into the open space; and in the center will be arranged the band stand, fountains, ornamental promenade, and pleasure grounds.

The old water reservoir has been preserved, and the southwest corner will be devoted to life saving, fire extinguishing apparatus, and hydraulic exhibits. On the northern side the ground will be arranged, showing the various stages of coal and lead mining in full working order. The open air exhibits will also be on this side of the building; and adjoining them will be the ornamental lake, on which it has recently been proposed that there should be erected a *fac-simile* of the old Tyne Bridge, with shops, as it existed prior to

the destructive flood in 1771. The whole of the western boundary will be occupied with the show of the Royal Agricultural Society, which will likewise be held in Newcastle next year. The area set apart for the mining exhibits will be about 2½ acres. The covered area for the exhibition will be 241,000 ft., while the covered area for the mining operations will be 59,000 ft., or together 300,000 ft. The entire building will be constructed of wood, and will be lighted from the top, with ventilating ridges over the whole of the course. The structure will be covered with Leeds cloth of a purple tint.—*Building News*.

BOLTON SEWAGE WORKS.

THE Bolton, England, sewage works, which were opened during the month of October last, form a good example of what may be termed the middle course in dealing with water-borne town refuse. The process adopted is the well known method of precipitation with lime, which throws down all the solids, and



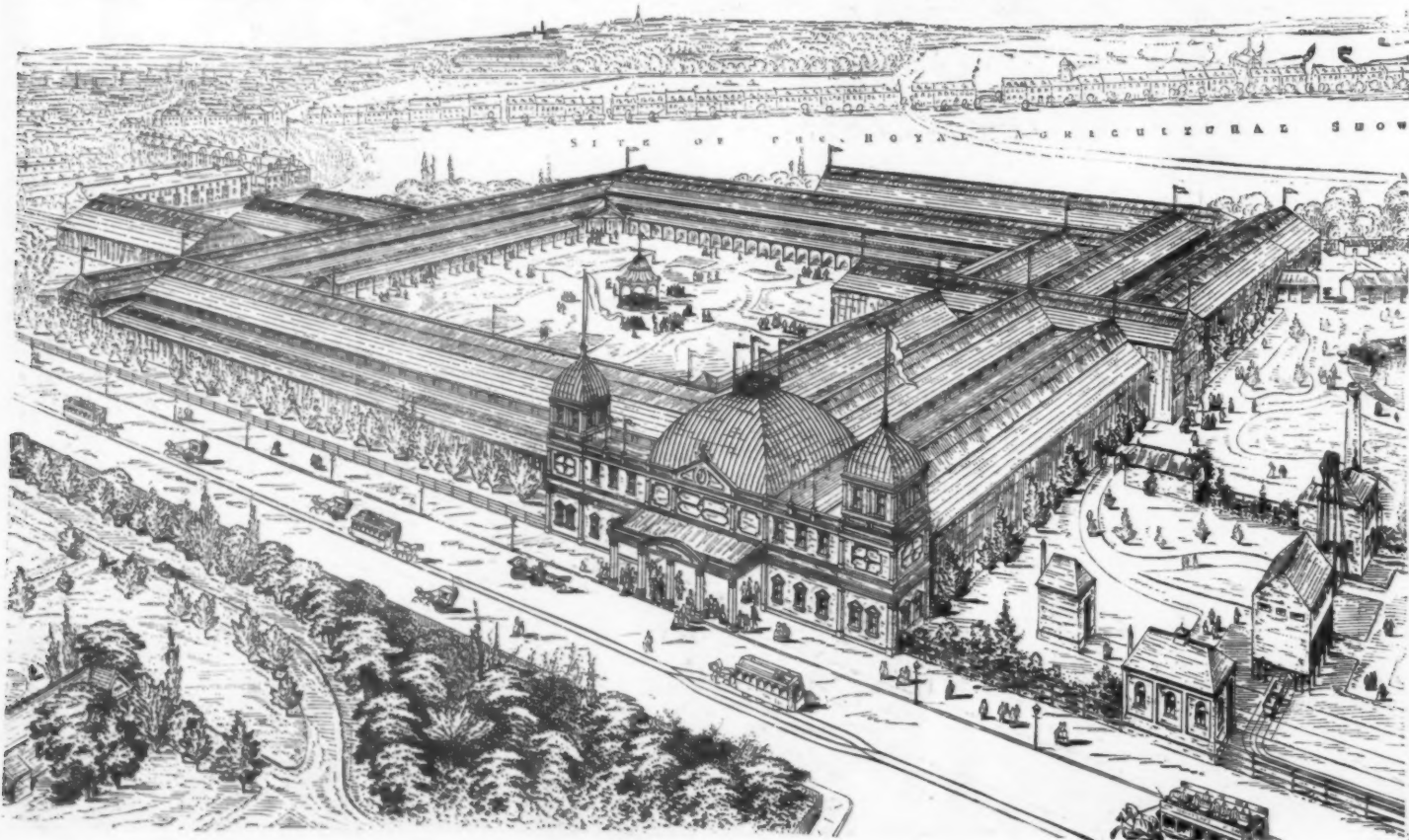
THE BOLTON SEWAGE WORKS.

renders the water clear and practically inodorous. The soluble constituents of the sewage are not dealt with, but pass away into the river, where they are, presumably, oxidized before they have time to undergo a change into the foul stage. Whether this is actually the case or not is a moot point; the scientific evidence offered to the Commission on the Metropolitan Sewage Discharge was opposed to this assumption, except in cases where the volume of the effluent was less than 5 per cent. of the stream into which it was turned. But in the two years which have elapsed since the evidence was taken, opinion has somewhat changed, and the Metropolitan Board of Works is now practicing precipitation on a large scale, in the hope that not only will they remove the 14 per cent. of solid matter, but that they will effect such a change upon the remaining 86 per cent. of soluble matter that it will cease to be a nuisance. They do not, however, confine themselves to lime, but use sulphuric acid and manganese in addition. Of course, it is open to the managers of the Bolton works to employ these reagents, or any other which science may discover, if it should be found that the lime is not an effectual medium. It would certainly be a matter for much congratulation if a thoroughly cheap and satisfactory precipitating agent could be discovered—one that would effect the purification of our rivers—for the process is not difficult to carry out, and the resulting sludge can now be dealt with, when

there is no land available for its reception, by means of filter presses, without much trouble. As will be seen from the description below, the cost of labor for carrying on a well designed works is very small.

The sewage of Bolton and other districts is collected by three intercepting sewers and delivered into the main outfall, which measures 6 ft. by 4 ft., and has a discharging capacity of 50 million gallons per day of twenty-four hours. The average daily quantity of sewage requiring to be treated at present is four million gallons. The milk of lime is introduced into the outfall at a point about a mile from the works, and thus becomes thoroughly mixed with the sewage during the passage of the latter. The lime is air-slaked in a cellar, from which it is raised by an archimedean screw to a rotary screen. The fine particles are then carried by an elevator to a cistern, where they meet with a jet of water, and the two run together to a mixing pit provided with a rotary stirrer; the overflow from this pit passes through a fine sieve into the sewer. The lime and sewage flow together to the precipitation works. These are very favorably situated on the banks of the River Croal, on a piece of sloping ground, which not only provides a fall from one set of tanks to another, but also leaves sufficient head in the last tanks that the purified effluent works a turbine on its way to the stream. The main outfall sewer ends in a catch pit, at the entrance to which there is a stone weir 14 ft. long, to allow storm water to escape direct to the river. The catch pit is 132 ft. long, 9 ft. deep, except at the ends, where it is reduced to 4 ft. by an inclined plane, and 7 ft. wide. Over it there is mounted a traveling dredger, running on rails, carried by brackets let into the side walls. By means of this dredger the matter caught in the pit can be removed without checking the flow. The heavy matter falls to the bottom, and floating pieces are caught by a screen with a one-half inch mesh fitted at the end of the catch pit. The screen is made of round bars, and scrapers are fitted to clean the spaces when they become choked. At the end of the catch pit there is a gauge basin measuring 15 ft. by 10 ft., and provided with a cast iron gauge 9 ft. long. The depth of water flowing over the gauge is read on a white enamel plate fixed to the wall, and from this the amount of sewage entering the works can be calculated. There is a second safety overflow to the storm sewer close to the gauge basin (see plan).

After the catch pit there come, in succession, three sets of tanks, called respectively the detritus tanks, the settling tanks, and the mud tanks. There are two of the first kind, each measuring 96 ft. by 48 ft.; they are 5½ ft. deep at the sides, and 8½ ft. deep at the center, the bottoms being gutter shaped. The sewage is delivered into these by brick-lined concrete conduits running the entire length, and provided with many outlets to secure an equal distribution. In these tanks all solids heavier than flocculent matter are deposited. Each tank has forty-nine cast iron trapped outlets fixed level with the top water line, and discharging into a conduit alongside. This conduit is 2 ft. wide, and is connected to a 24 in. pipe running beneath the floor and along the center of each tank. The sewage which escapes by this pipe enters one of the three settling tanks, each of which is 297 ft. by 96 ft. by 6 ft. The floor is formed in three sections, each of which resembles an inverted pyramid, and at the apex of each there is an inlet supplied by a pipe for the detritus tank. This pipe is 24 in. in diameter to the first inlet, and is then reduced to 18 in. When a settling tank has been filled, it is left perfectly quiescent for a time for the mud to settle to the bottom, and then the clear liquid is decanted off by six automatic floats, each of which has a mouth 2 ft. 6 in. by 6 in., gradually tapering to a 9 in. outlet. Each float is attached to its branch by means of a V joint with brass facings, supported in the center and at the ends by a wrought iron shaft 3 in. in diameter. The purified



INDUSTRIAL EXHIBITION, NEWCASTLE-UPON-TYNE, 1887.

sewage can either be discharged directly into the river or it can be sent through a turbine which works the mud pump, the conditions being such that 50,000 cubic feet of effluent will lift 7,500 cubic feet of mud to a height of 25 ft. A small branch from the discharge pipe leads to a fountain which is employed to show the color of the water.

Having thus traced the course of the water, we will return to the solid matter which it carries with it through the sewer. The gravel and heavy matter is dropped into the catch pit, from which it is removed by a dredger without interference with the flow; the cotton waste is also left here, as it cannot pass the screen, while a good deal of floating fat is detained by a curtain which dips a foot below the surface. All the solids heavier than flocculent matter are left in the detritus tanks, and are removed from time to time by 6 in. pipes, which communicate with the pump, the surface water having been previously decanted off by a floating pipe. The remaining mud is left in the settling tanks, each of which will contain one day's supply of sewage. It is delivered into mud tanks, of which there are two, each 99 ft. by 47 ft., and from these it is pumped on to the adjoining land.

The total cost of the works may be taken as follows:

	£	s.	d.
Land	12,394	2	6
Tanks, turbine house, gates, railing, fence, roads, and sundries.	10,556	8	4
Iron pipes, penstocks, floats, screen, dredger, valves, castings, turbine, and pump.....	2000	0	0
Bridge and approaches, gate-house, laying out the grounds, furnishing, and incidentals.....	3500	0	0
Estimated further expenditure, including unpaid accounts and balances.....	2500	0	0
Total.....	30,850	10	10

This is about 4000l. less than was estimated by Mr. J. Proctor, the borough engineer, who has designed and carried out these works, which will probably receive a great deal of attention and appreciation at the hands of those interested in the purification of our rivers.—*Engineering.*

REPAIRING BROKEN CRANK SHAFTS.

The illustrations below, taken from photographs, show a crank shaft of large size for the Monarch Line,

REMARKS.—The piece marked O 739 was bent cold through an angle of 162° before fracture; the other marked O 740, was bent cold through an angle of 169° before fracture.

It will be seen that by this method of repairing crank shafts, the broken shaft, when repaired, becomes essentially a built shaft, without the disadvantage of having a large mass of unbalanced material at the crank pin end of the webs; and should a subsequent fracture occur, only that portion to which the fracture is confined need be replaced. It has been practically proved that the various operations necessary in repairing a crank shaft on this plan can be performed so as to leave the finished crank shaft perfectly true. It is unnecessary here to point out the saving effected by this invention, enabling, as it does, condemned and hitherto worthless crank shafts to be made equal to new, and in every way available for further use.—*Industries.*

CAR LUBRICATION.

At a recent meeting of the Engineers' Club of Philadelphia, the secretary presented, for Mr. W. E. Hall, a paper on car lubrication. What will be the result of the many attempts to improve the present condition of car lubrication, and to overcome some or all of the various annoyances—particularly that of the heating of journals and brasses—which are now connected with this important part of the transportation and motive power departments of railroads, is a matter of great interest.

The distinction between good and bad lubrication is simply a comparative one. Efforts should always be directed toward reducing the frictional resistance and wear of journals and bearings, upon which, with the quantity and quality of lubricant required per car per mile, depends the economy of the results.

The method of lubrication which is now used for passenger and freight car journals is somewhat imperfect at its best, and much more so as carried out in railroad work. The principle of its action is that the material used in the boxes—whether fibrous, cotton or woolen waste—is of such a nature as to retain the oil, and, it is claimed, to draw it from the bottom of the oil box to the journal with which the waste is in contact.

From the manner of attending to car oil boxes, it is found that the waste, from the frequent but small supplies of oil which it receives, does not reach its best condition—that is, become thoroughly saturated in the upper part, or that next to the journal, and able to retain a

waste packing closer and tighter than the woolen waste.

Reliable experiments of Mr. Tower have shown that, with the several methods of lubricating, the comparative frictional resistances are:

Oil bath	1
Pad saturated with oil under and in contact with journal.....	6.48
Siphon lubricator.....	7.06

COLLODIO-BROMIDE EMULSION PROCESS FOR LANTERN SLIDES.

A COMMUNICATION to the London and Provincial Photographic Association on the above subject, by a skillful worker, Mr. J. B. B. Wellington, we find reported as follows, in the *Br. Jour. of Photo.*:

I will commence with the practical part, and show you how the emulsion is made, which differs but little from Mr. Nesbitt's original formula:

Methylated spirit	3 ounces.
Methylated ether (0.725).....	2 3/4 "
Pyroxyline (high temp.).....	1 drachm.
Methylated spirit.....	1 ounce.
Water.....	1 1/2 drachms.
Ammonium bromide	65 grains.
Citric acid.....	5 "
Silver nitrate.....	100 grains.
Citric acid.....	5 "
Water.....	2 drachms.

Place the pyroxyline in a ten ounce bottle, pour in the spirit, and finally the ether; shake the bottle well, when the cotton will dissolve. The ammonium bromide is next weighed out, together with the citric acid, placed in a test tube with the one and a half drachms of water; dissolve by heat, and add the spirit, and add this to the collodion already made in the ten ounce bottle, and shake well. Now dissolve the silver and citric acid in a small test tube together with the two drachms of water (in both cases hard water will do, as the citric acid dissolves any lime that may be present; its chief function—citric acid—is to give a fine emulsion).

Take the tube of silver and the bottle of collodion into the dark room, add the silver a few drops at a time to the collodion, well shaking after each addition. The emulsion should be of a good orange-ruby color when a drop is examined by transmitted light, and should show no granularity with a magnifier. It should be kept a day, and then poured out into a flat dish to evaporate—of course, in the dark. After twelve hours it will be firm enough to wash; break up into little pieces about a quarter of an inch square, place these in a jar of water, which ought to be changed at intervals of about half an hour. It is advisable to collect the pieces and place them in a handkerchief and give them a good squeezing. This gets rid of a lot of the salts. When this has been done five or six times, place the pieces, after squeezing as much water out of them as possible, into methylated spirit, sufficient to just cover them, and do this three times in all; this is done to abstract every particle of water, which, if left in, would produce crapy markings in the water plate. Transfer the pieces into a ten ounce bottle, and add four ounces methylated spirit and four ounces ether, and shake the whole together till dissolved. It is now ready for filtering, which is easily accomplished by taking a half sheet of clean rice paper, and make a cone of it, leaving a one-eighth aperture at the bottom. A tuft of clean cotton wool is gently pressed into this and the emulsion poured through, when it should just run through in a continuous stream. It is advisable to re-filter the first ounce that passes through, to get rid of any stray bit of cotton that may have passed. Two bottles should be used for coating, one containing the filtered emulsion, and the other to receive the excess from the plate after coating, which, when full, should be filtered back to the filtered bottle. On no account should the excess be poured back into the same bottle you use to coat from. When the emulsion becomes too thick from constant evaporation, more ether and spirit must be added, rather more of the former than the latter, as ether evaporates more quickly than does the spirit.

Before coating a plate I must say something on the preparation of the glass. When I first took up this process, I used to employ old gelatine negatives, which I cleaned in acid and water, and then scrubbing off with hot water and standing them up to dry. Things went very well, never such a thing as a film slipping, until I bought some new glass, which I cleaned the same way—namely, in acid and water; but invariably the film would come off and disappear down the sink; this annoyed me very much. I tried French chalk; although it kept the film on, I considered it a dirty job, as a quantity would remain on the edge of the glass, which was bound to find its way into the emulsion. I pondered over this film slipping for some time, when it suddenly struck me that possibly the gelatine on the old negatives had something to do with keeping the film on, and found on trial that this was so. I now use the following to clean glass:

Gelatine.....	200 grains.
Nitric acid.....	1 1/2 ounces.
Water	20 ounces.

The gelatine is soaked in cold water and dissolved by heat. Place the glasses one by one into the warm solution for one or two minutes, and then well scrub under the tap; I prefer hot water, as the plates are less likely to have tear drops form during drying, and they also dry in a much quicker time.

The glasses are placed in racks to dry spontaneously, and should not again be touched previous to coating. I have never been troubled with films slipping with glass treated in this way. I think I have knocked all kinds of substratums on the head at last. Coating a plate with a substratum is, in my opinion, a serious drawback to the collodion process, as it involves the trouble of two coatings to one plate. It is preferable to allow the plate, after being coated with emulsion, to dry spontaneously, which it will do in about half an hour. Plates should not be used that have been coated more than a month. My experience is that spots appear to develop themselves. Others have used them over six months old. Probably gas may be the cause of my failure. However, it is best to use them up soon after coating.

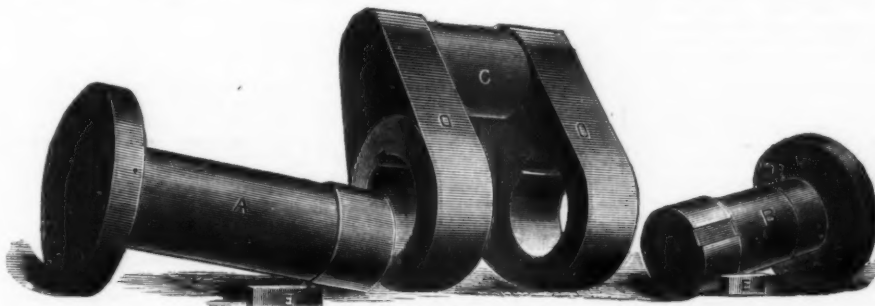


FIG. 1.

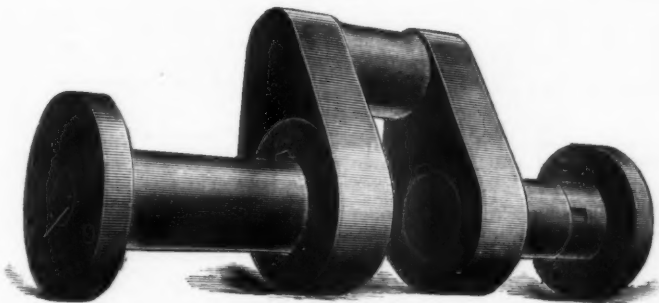


FIG. 2.

REPAIRING BROKEN CRANK SHAFTS.

repaired on Foster's patent plan by Messrs. John Spencer & Sons, Newburn Steel Works, Newcastle-on-Tyne. The crank shaft, which was 16 in. in diameter and 2 ft. 4 1/2 in. throw, was condemned on account of a flaw in the crank pin. The faulty crank pin and webs were cut off, leaving the shafts A and B (Fig. 1) as shown, with the bosses where the crank webs had previously been; another crank pin, C, together with its crank webs, D D, cast in one piece, was substituted, and the whole shrunk together, and afterward further secured by means of keys, E E; the complete crank shaft, weighing over 6 tons, being shown in Fig. 2. This crank shaft being under Board of Trade and Lloyds' survey, it was necessary that the new part of the shaft should satisfy their conditions of test. For this purpose tensile and transverse test pieces were cut from the crank webs, and tested in the presence of Board of Trade and Lloyds' surveyors, giving the following results:

	Mark of Test.	
	O 739	O 740
Size of specimen, diam. in.....	0.753	0.753
Original area, sq. in.....	0.4453	0.4441
Fractured area, sq. in.....	0.1555	0.2248
Permanent set induced, tons per sq. in.....	17.043	19.60
Maximum strain, tons per sq. in.....	27.34	33.18
Contraction of area, per cent.....	65.08	49.38
Elongation in length of 5 in. per cent.....	24.5	18.0
Appearance of fracture, silky..	100	100
Date of test, July 26, 1886.		

larger percentage of oil—until after it has made considerable mileage, and then it is that the lubrication of the journal obtained by this method is the most efficient. New waste, when put into boxes, will always make the journals reach a higher "running heat," which, although advantageous in increasing the fluidity of the lubricant, and, therefore, decreasing the coefficient of friction, is yet objectionable in reducing the condition of lubrication to a more sensitive one, and one more likely to influence the production of hot journals. For this latter reason a low "running heat" of say seventy-five (75) degrees Fah., while giving somewhat higher frictional resistance, is preferable. It is always advisable to saturate new waste as thoroughly and as long as possible before placing it in car boxes, and to use waste, when repacking, that has seen more or less service, provided it does not contain sand or grit.

It will, then, be noticed, in the present method of lubricating car journals, that immediately after the box has been oiled the top of the waste is well saturated and all in good condition; but, in a short time, the waste in contact with the journal will lose what oil it may contain, by its falling to the bottom of the box, dissipation, and leakage at the mouth and back.

While the box may contain abundance of oil at the bottom, the top of the waste, where it is desired the oil should be, is comparatively dry and inefficient. In this particular a mixture of woolen and cotton waste—about half and half—is found to give better service than either used alone. The woolen waste has the elasticity, and the cotton waste, while not absorbing as well, seems to keep the oil in the desired position better than the former. This is due to the cotton

Great care must be used when making a slide by contact, as the slightest movement, when in contact with the negative, will so abrade its surface, owing to its tender nature, as to become useless; but practice will soon overcome this.

The exposure from a clear negative of average density, 1½ from a gas flame, will be one to three minutes; but, if the negative is at all yellow, twenty or thirty times the exposure will be required; but only a few trials will determine this. The longer the exposure, the warmer and redder the tone, and, consequently, the more rapidly will the plate develop.

For reducing in the camera by daylight on a clear, dull day, with No. 13 stop, V. S. about two minutes, I cannot get such rich tones as when I reduce on a clear, dull day, raining perhaps, at the same time, which, I find, is much better than a bright, sun-shining day. Is this the experience of others? I presume it is analogous to our being able to produce a better print on albumenized paper in the shade than in the sun.

The formula I use is a modification of Beach's well known potash developer, with the addition of bromide. The first two solutions I employ for developing gelatine plates, thus obviating the necessity of having a lot of bottles knocking about the developing room.

Pyro.....	1 ounce.
Sulphite of soda.....	4 ounces.
Citric acid.....	100 grains.
Water to make.....	18 ounces.
Carbonate of potassium.....	3 ounces.
Sulphite of soda.....	2 "
Water to make.....	18 "
Ammonium bromide.....	120 grains.
Water.....	10 ounces.

Take one drachm of each of the above solutions, and mix; this forms the developer without the addition of any more water. (I just mention here I use for a gelatine plate, one drachm of the pyro solution and one drachm of the potash to two ounces of water.)

After exposure, the plate is held by one of the corners, and flowed over with methylated spirit for half a minute, and then rinsed under the tap until all greasiness disappears; the developer is now applied, still holding the plate by the corner (no dish is required), and continually pour the developer on and off, holding the plate against the lamp to watch the density; when sufficient, immerse in not too strong a bath of hypo. The development ought to be complete in less than a minute. Wash the plate for a minute or so under the tap, and it can then be dried by heat, or spontaneously, and this completes the whole operation.

Before closing, let me say I have tried various alterations to the developer. For instance, I have replaced half of the potash carbonate with ammonium carbonate, and have also used sulphite ammonia instead of soda, all of which, at the time of trying, I thought gave me better results, but have returned to my original formula. More depends upon the light and exposure than anything else. I strongly condemn varnishing the plate before mounting; there is no necessity, as the film is perfectly clear when the plate has been developed with the above formula. However, when liquor ammonia has been used, varnishing must be resorted to, to get rid of the opalescence caused by the ammonia. One of the drawbacks, when varnishing, is dust settling on the film, and when there, certainly does not add to the beauty of the slide.

On the same subject, before the Glossop Dale Photographic Society, Mr. S. Bamforth spoke as follows, which we extract from the *Photo. News*:

The first operation was to clean the glass thoroughly by means of wash leather and French chalk, so removing all trace of grease. The plate should then be edged with the rubber solution by means of a piece of wash leather formed into a small pad, or a piece of cork would do as well. This would prevent the solution from running over the edge. The plate was then coated with Brook's emulsion, which is in the form of cream, and consisting of—

Carbonate bromine (crystals).....	30 grains
Ammonium bromide.....	15 "
Methylated alcohol 0.830.....	3 ounces
Pyro.....	20 grains
Sulphate ether.....	2½ ounces

<i>Sensitizer.</i>	
Silver nitrate.....	50 grains
Water.....	30 minims

Add alcohol heated until the water has evaporated, then wash. Take up the glass to be coated with a pneumatic holder, and pour sufficient of the emulsion to cover the plate, and drain off into the bottle again; then place the plate to dry. The box used for this purpose by the lecturer consisted of a biscuit box, in which was placed a paraffin lamp. This acted both as a drying box and a lamp for developing, by cutting away part of one side, and substituting a sheet of yellow paper. At the top of the box, and outside, was placed a plate which became heated, and on this the coated plate was put to dry, raised slightly at an angle, so that it was not in immediate contact. The printing frame is made with the back sufficiently large that the negative can be moved in all directions, and so obtain any particular part of the picture by placing over it a mask the exact size of the plate, the negative being held in position by means of drawing pins. The films of a collodion plate, being of a very tender nature, require more care than the gelatine, and are best when used soon after coating, as they will not keep. The plate, when dry, is placed in position on the negative in the printing frame, and exposed to magnesium light of (say) one and a half inches of wire (for an ordinary negative), one foot from the printing frame. The film, being of a horny nature, is placed in a solution of—

Methylated alcohol.....	2 parts
Water.....	1 part
Nitric acid.....	15 drops

The plate should then be well washed before using the developer, which consists of—

<i>Solution A.</i>	
Saturated solution of ammonium carbonate.....	4 ounces
Potassium bromide.....	1 drachm
Acetate soda.....	2 drachms
Water.....	8 ounces

Solution B.

Pyro.....	96 grains
Rectified alcohol.....	1 ounce

Developer.

Solution A.....	2 drachms
" B.....	10 to 30 drops
Water.....	2 ounces

In developing, it is preferable to use a glass dish. The progress of the development may then be watched more easily by transmitted light. When sufficient depth has been obtained, the plate should be thoroughly washed, and placed in a fixing solution of—

Cyanide of potassium.....	30 grains
Water.....	1 ounce

Should the picture be found too dense, allow it to remain in this solution for a short time, which will act as a reducer. If necessary, the picture may be toned in a solution of the following proportions:

Bichromate of platinum.....	1 grain
Nitric acid.....	1 drop
Water.....	3 ounces

It will be found that collodion emulsion is far less sensitive than gelatine. If the picture appears to be weak, it may be intensified by—

Solution A.

Pyro.....	1½ grains
Water.....	1 ounce

Solution B.

Nitrate of silver.....	30 grains
Citric acid.....	30 "
Nitric acid.....	10 minims
Water.....	1 ounce

Take solution A, and add one or two drops of solution B; if not strong enough, add another drop, until the required strength is attained. The plates should then be well washed before drying.

IMPROVED KILN FOR BRICKS, LIME, AND CEMENT.

THERE has just been erected at Rose Hill, between Manchester and Macclesfield, an improved patent chamber kiln of the "Hoffmann" type, first brought out in Germany about thirty years ago by the inventor of that name. The present kiln—the "Hertrampf"—is an improvement on Hoffmann's, since, in the new kiln, one chamber or oven containing the raw and damp material is shut off from the direct action of the fire in the burning chambers by a removable iron shutter, the raw material therein being dried, previous to firing, by a continuous current of pure hot air, produced by the chambers which are "in fire." This current is properly distributed through the raw material in the "drying chamber," and is delivered into this chamber at a temperature of 800° F. to 900° F. The result obtained from this great heat is that the raw material is thoroughly dried and freed from every trace of moisture before being brought into fire—practically the material is half burnt.

One of the greatest evils of the ordinary plain "Hoffmann" kiln is that wet or imperfectly dried raw material is brought into direct contact with the fire, the result of which is that a large proportion of this material is discolored by the smoke and products of combustion, and is cracked by the too sudden release of moisture. It, too, comes out "spotty," or of a bad and unequal color, and consequently greatly diminished in value. Supposing bricks to be the material to be burnt, these may be put into the drying chamber of the "Hertrampf" kiln as soon as they have acquired sufficient cohesion to sustain their own weight, or say after ten days' natural drying in the ordinary sheds or open air. This cannot be done with the ordinary "Hoffmann" or any other chamber kiln, as the bricks or other material would be worthless if so treated.

A reference to the annexed plan will show the shape and general arrangement of the kiln just now completed at Rose Hill. This kiln is intended for both brick and lime burning, and has been built for Messrs. J. & M. Tyum, brick and lime burners, of Marple and Rose Hill, by Mr. F. H. Jung, of 86 Stanley Grove, Longsight, Manchester, who holds the sole patent right for the United Kingdom from the German patentee, Mr. Otto Hertrampf, of Breslau. The kiln contains sixteen ovens or chambers, having arched roofs, or rather a continuous arched roof round the kiln, these chambers being arranged in the form of an oval ring. The partitions between each chamber consist of removable light iron shutters.

Running round the entire circumference of the kiln outside the chambers, i. e., between the chambers and the outer wall, is a main hot air flue, 18 in. by 18 in., at a level of about 6 ft. above the floor of the chambers, and having connection by dampers with each of the sixteen chambers. A main smoke flue, 5 ft. high by 4 ft. 6 in. wide, runs down the center of the kiln for its entire length, its floor being at a level of about 3 ft. above the floor of the chambers. Every chamber has also direct connection into this main smoke flue, through dampers. The chimney of the kiln, as shown on plan, is nearly in the center of the smoke flue, access to which for cleaning is obtained by means of two manholes, M M, placed equidistant between the chimney and the two ends. Each of the sixteen chambers contains three separate sets or ranges of air flues (together with their respective single connecting flues), forming two distinct systems to each chamber.

The first system is for producing a continuous supply of hot air, and consists of a range of six vertical air shafts formed in the brick lining on each side of every chamber, and having connection with the fresh outside air through three horizontal single flues formed under the floor of each chamber, and also with the main hot air flue through two horizontal single collecting flues formed in the roof of each chamber, one on each side. The second system consists of a range of four horizontal air flues formed in the brick roof of each chamber, but this second system is only in use in one chamber at a time, this being the particular chamber which then happens to be in work as a drying chamber. The purpose of this second or distributive system of flues is to feed the drying chamber with hot air from the main hot air flue—this latter being sup-

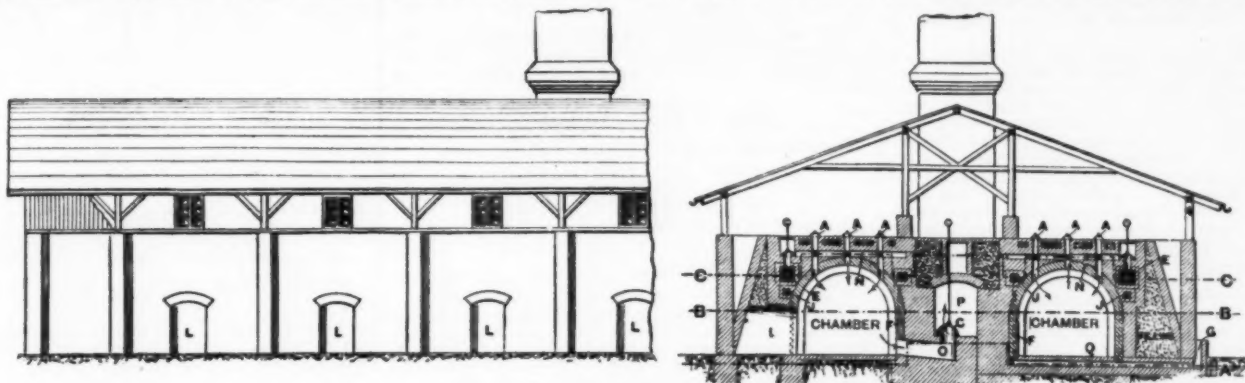
plied by the "producing flues" or "first system," as explained above. The whole of the flues before mentioned, whether main or otherwise, are controlled by dampers. To begin from the outside of the kiln, the fresh air inlets, or ventilis, leading to the producing flues are provided with a damper to each chamber. Next after these come the producing flues themselves, which have also one damper to each chamber, placed at the junction of the two single horizontal collecting flues, and at the point of their discharge into the main hot air flue. Also placed at regular intervals in the main hot air flue are the dampers—one to each chamber—which control the supply of hot air from that flue to the distributive systems of flues before described. In addition to all these, there are the smoke dampers, the whole of which are placed on the floor of the main smoke flue. These dampers are used not only for passing the smoke and products of combustion from the "burning chambers," but also bring into action the draught of the chimney for inducing the hot air current from the producing flues of the burning chambers to the drying chamber, the current traversing the main hot air flue in its passage to the latter. The main hot air flue is also provided with sixteen dampers, placed at intervals of a chamber's length. At this point it will be well to explain that the coal for "firing" the burning chambers is fed into them through a series of nine vertical circular openings 6 in. diameter, cut through the brick roof of each chamber. These firing holes are arranged in parallel rows of three holes to each row, and three rows to each chamber, the rows running crosswise of the chambers, i. e., at right angles to the side walls, and are provided with loose cast iron covers, and are also lined with light cast iron tubes. The total outside length of the Rose Hill kiln is 112 ft., width 42 ft., thickness of outside wall 6 ft. 6 in., thickness of inside wall 3 ft. 6 in., size of the twelve rectangular chambers, 13 ft. 6 in. long by 9 ft. wide by 8 ft. high to crown of arch. The cubical contents of each of the four irregular chambers are the same as in the rectangular chambers. Height of chimney, 135 ft.; capacity of each chamber = 7,500 bricks; or 50 tons of raw limestone, producing 25 tons of lime.

Production per week: Bricks = 10 chambers, or 75,000 bricks; lime = 12 to 14 chambers, or 300 to 350 tons. This kiln being principally for lime burning has the whole of the chambers lined with fire brick; but this is not necessary in a kiln for burning ordinary bricks, the inside of the chambers in that case being formed of the common brick used in building the kiln throughout. The fire brick lining is, however, necessary also in kilns for burning cement. The height of the chimney is of course determined by the size of the kiln and the aggregate length of the systems of flues to be worked at one time. The plan along the line, C C, shows the distributive systems of horizontal flues, referred to hereafter as N N, and also the single horizontal flues (J J) from the inner ranges of vertical air shafts (F F). The single horizontal collecting flues from the outer ranges of vertical air shafts, being underneath the main hot air flue, E E, are not shown on this plan, but their position will be found at J J, on the sectional elevation. The half sectional plan along the line, A A, shows the horizontal fresh air flues, Q Q, below the floor of the chambers which feed each separate range of vertical air shafts, F F. The half sectional plan along the line, B B, shows the vertical air shafts or producing flues, F F, in the fire brick lining, H H, of sides of chambers, there being twelve of these shafts to each chamber, i. e., six on each side. The iron shutters, B B, between each chamber, and the hot air inlets, K K, at the floor line (one to each chamber), are also shown on this plan. The hot air inlets, K K, are fed from the main hot air flues, E E, by a single vertical shaft to each, and draw a portion of the hot air therefrom into each chamber at the floor line. These inlets, like the distributive flues, N N, are only to work in one chamber at a time, i. e., the drying chamber. The sectional elevation of the kiln shows the positions of the main and branch smoke flues, P and O, the main hot air flue, E, the collecting flues, J, the vertical air shafts, F, the fresh air flues, Q, the distributive flues, N N, and the firing holes, A A. Having now given a general idea of the kiln, we will proceed to illustrate, by reference to the plan, the principle upon which it is worked. Suppose chambers Nos. 1, 2, and 3 are in fire respectively. The coal is fed through the firing holes, A A. The order in which the chambers are to be used is in the progressive order in which they are numbered, or from Nos. 1, 2, and 3 to Nos. 4, 5, and 6, three chambers being always in fire at once. Assuming, then, that Nos. 1, 2, and 3 are in fire, the five iron shutters or partitions, B B, which ordinarily divide chambers Nos. 1 to 6 are removed from their places, thus converting these six chambers into one large one, the live fire from Nos. 1, 2, and 3 chambers having thereby uninterrupted scope for its action through the entire range of six chambers. The main smoke flue dampers, C C, are, in all the chambers, connected into the branch smoke flues, O O, at the floor line of the chambers, and at the extreme end thereof, i. e., at the point furthest from that end at which the fire approaches. The object of this arrangement is to compel the fire or hot air, as the case may be, to traverse the entire length of the chamber or chambers to the furthest possible point, and thus obtain the maximum amount of work from it before it passes into the main smoke flue, P P, and thence away into the chimney, D. In the example under notice, the smoke flue dampers, C C, of chambers Nos. 1, 2, 3, 4, and 5 are all closed, only the damper, C, of No. 6 being opened. The fire from chambers Nos. 1, 2, and 3 is thus forced to traverse chambers Nos. 4, 5, and 6 before it can pass away into the main smoke flue and chimney. These six chambers, Nos. 1 to 6, are styled the burning chambers. No. 7 chamber, the next in succession in the direction in which the fire is traveling, is now in use as a drying chamber for raw material. This chamber is perfectly air tight as regards the outside atmosphere, and also as regards the six burning chambers, the iron shutters or partitions, B B, being in position between chambers Nos. 6 and 7 and Nos. 7 and 8. The smoke flue damper, C, of No. 7 chamber is, on the other hand, open, and connection between this chamber and the chimney, D, being thus established, a current is set up in the direction of the arrows marked on plan, from the chamber to the chimney, D. Now, this outward current could not, of course, exist without being fed by a constant inward current. This is obtained from the main hot air flue,

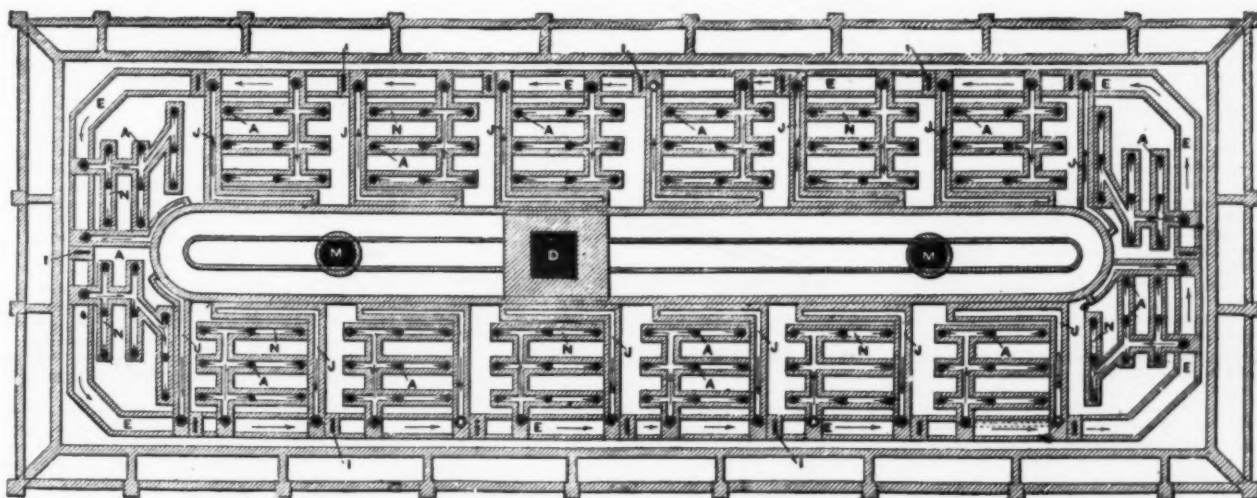
E E, which latter is supplied from the vertical air shafts or producing flues, F F, of the three burning chambers Nos. 1, 2, and 3, these producing flues being in their turn supplied with fresh cold air from outside through the inlets or vents, G G, and thence through the horizontal single flues, Q Q. The inlets or vents, G G, are opened by lifting out the loose iron caps or covers with which each is provided. The vertical producing flues, F F, in the three burning chambers Nos. 1, 2, and 3 become intensely heated, the fire brick linings, H H, in which they are formed attaining almost a white heat. The three vents, G G, then being open, and the six dampers, I I, of the main hot air flue, E E, being also open, a strong inrush of fresh air is set up through the vents, G G, which, in its forced passage through the producing flues, becomes

being the length of time which the order of working the kiln will allow) to the action of this hot current, the lime (or other raw material) is ready for actual firing or burning. Practically, as before stated, it is already half burnt, and thus incapable of discoloration or other injury by direct action of the fire, as is invariably the case when imperfectly dried material is exposed to the direct action of the fire. The drying process then by this time being completed in No. 7 chamber, the iron shutter, B, between chambers Nos. 6 and 7, is removed, and No. 7 chamber thereby becomes in turn a burning chamber. Chamber No. 8, holding fresh raw material, is then treated as a drying chamber, the method being an exact repetition of that by which the last chamber (No. 7) has been worked. During the eighteen hours which are supposed just to have elapsed, the lime or

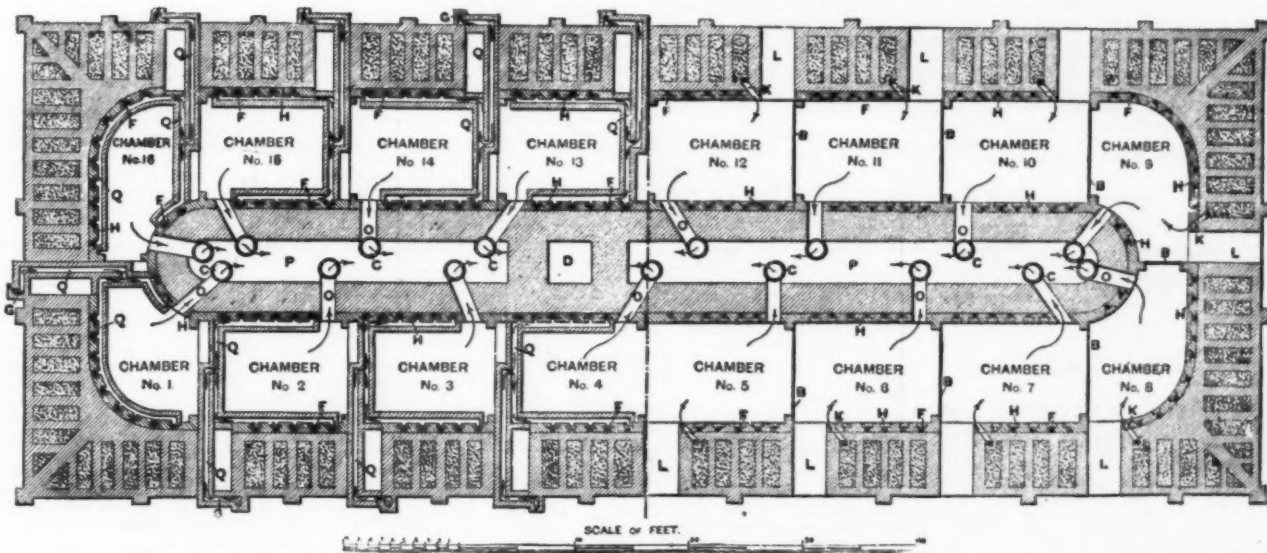
moulded bricks is—where this kiln is used—reduced to about ten days; whereas with a common field kiln the bricks, as a rule, must be dried either in the usual sheds or in the open air for a period of three or four weeks before they are fit to be put in the kiln. As a result of this latter method, a much larger space of ground is covered by wet bricks undergoing the preliminary drying, and much valuable time is lost in bringing up to the kiln, from distant parts of the drying field, those bricks which are sufficiently dry to be put into the kiln; (5) a large saving of drying area and brick sheds, as explained in the preceding item, a much smaller quantity of wet bricks being out at any one time; (6) the large proportion—80 per cent.—of prime quality face bricks fit for using on outsides of buildings; the patentee guarantees this proportion, and also a total



EXTERNAL AND SECTIONAL ELEVATIONS.



SECTIONAL PLAN ALONG LINE C C.



HALF SECTIONAL PLAN ALONG LINE A A.

HALF SECTIONAL PLAN ALONG LINE B B.

IMPROVED KILN FOR BRICKS, LIME, AND CEMENT.

intensely heated. The single horizontal collecting flues, J J, in the roofs of the burning chambers Nos. 1, 2, and 3 then conduct this heated air into the main hot air flue, E E, from the six ranges of producing flues in the three burning chambers, whence it is carried by the draught of the chimney, D, through the four horizontal roof flues of the distributive system, N N, into the drying chamber No. 7, down the firing holes, A A, its ascertained temperature on passing into this chamber being 800° F. to 900° F. A portion of this heated air also passes into the chamber at the floor line through the inlet, K, which has an independent connection by a single vertical shaft to the main hot air flue, E E. This temperature is maintained in the drying chamber by the constant current of hot air, which evaporates every trace of moisture from the raw material (lime, bricks, or cement, as the case may be), and carries it off to the chimney, D, through the damper, C, and after being exposed for eighteen hours (this

other material in No. 1 chamber has been sufficiently burnt, and is ready for removal directly it is cool (lime requiring twelve hours' actual burning, and bricks eighteen hours). The firing is advanced at the rate of one row of the firing holes, A A, every five hours in brick burning, and every four hours in lime burning. Direct access to each chamber from the outside for charging and emptying is given by the arched passages or entrances, L L. With proper management, once the kiln is fired, the work should go on continuously without break, and the fire need not be allowed to die out more than once every year, unless for some special purpose. The patentee claims for this kiln the following additional advantages, viz.: (1) a saving of coal of at least 25 per cent. as compared with the ordinary "Hoffmann" kiln; (2) a saving of time in burning of one-fifth; (3) an increase of 20 per cent. in production; (4) a great saving of time in charging the kiln. The time required for the ordinary natural air drying of plastic or newly

production of 6,000 bricks per ton of coal consumed; (7) the uniform color of the bricks. This also applies equally to lime and cement. The quantity of bricks used in building the Rose Hill kiln is about 400,000, and much of the mortar used is clay mortar. A kiln for burning lime requires stronger walls and greater strength in general construction than one for burning bricks only.

The Rose Hill kiln is capable of producing annually 3,500,000 bricks or 170,000 tons of lime. "Hertrampf" kilns are built of various sizes, and to produce from 2,000,000 to 8,000,000 bricks per year. For a producing capacity of 5,000,000 bricks and upward, a double kiln of thirty chambers is required. It should be stated that the "Hertrampf" kiln is covered with an ordinary slate roof, the sides being boarded up from the top of the outer wall of the kiln to the eaves of the roof. The kiln is therefore quite protected from the weather, and there is no loss of heat from radiation.—Industries.

FRICTION.*

BY PROFESSOR H. S. HELE-SHAW.

Lecture I.—Delivered January 11, 1886.

THE FRICTION OF SOLIDS.

If we place the surfaces of two bodies in contact, and press them together, we are conscious of a resistance opposing any attempt to move one over the other. This resistance is reduced by diminishing the roughness of the surfaces and decreasing the pressure, but it can never be caused to disappear, no matter how smooth the bodies are made or however small the force acting between them. This opposing force is called the *resistance of friction*. Not only does a resistance to relative motion occur between the external surfaces of bodies, but between the internal parts of both solids and fluids, and to this resistance the term "friction" is likewise applied.

We shall hereafter have occasion to carefully discuss whether or not the use of the same word for the phenomena of this kind both for solids and fluids is advisable; but it is evident that, taking the word in its present general sense, the subject of friction covers a very wide field, and has an importance which, whether we regard it from a purely practical point of view or in its scientific aspect, is not easy to realize. The object of this course of lectures is to gather together the facts concerning the nature and application of friction which have gradually become known, and present them in such a manner as to enable a clear grasp as possible of the whole subject to be obtained. It will be impossible, in the four lectures before us, to give more than an outline of the above facts, but my aim throughout will be to adopt a method of treatment at once elementary and complete, and to bring forward such data and experiments as may best illustrate the general principles of the subject. In the present lecture we shall study the friction of solid bodies; in the next the nature and laws of fluid friction, the term "fluid" including both liquids and gases. The third lecture will deal with the mechanical applications of friction, while in the fourth we shall regard friction from the opposite point of view, viz., as a resisting force which is always being brought into action, and which the practical man, and particularly the engineer, finds it necessary to take into consideration in all mechanical problems. In short, while the first two lectures deal with the nature and laws of friction, the last two will respectively treat of it in its useful and prejudicial aspects.

THE FRICTION OF SOLIDS.

About 100 years ago the celebrated French philosopher Coulomb enunciated certain general truths as the result of his own investigations and those of previous workers on the subject of friction. He stated that, with certain exceptions, the resistance of friction of solid bodies, 1, varied directly as the pressure between the surfaces in contact; 2, that it was independent of the extent of those surfaces; and, 3, that it was independent of the velocity of their relative motion over each other. These truths, which have ever since been known as the laws of friction, were examined by means of a very large number of experiments, conducted at the expense of the French Government by General Morin, who confirmed in the main their accuracy for the comparatively limited range over which he extended his observations. Coulomb's laws, which are capable of expression in a very simple mathematical form, and hence are easily employed in numerical calculations, have, in consequence, been until a recent period adopted universally and relied on implicitly, not only within the limits of Morin's experiments, but beyond them. For this reason, and also in order to enable the modifications which are the result of more recent researches to be afterward better understood, it will be advisable to study them rather carefully, and especially their mathematical form of expression. We shall best be able to do this by studying Morin's method of experiment, which will be made clear by the help of the rough model of his apparatus before you. That apparatus (Fig. 1) consisted of a loaded box, D, resting on a slider,

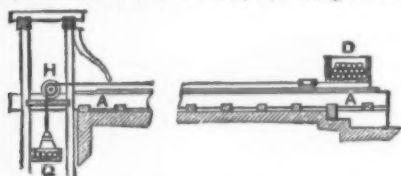


FIG. 1.—MORIN'S APPARATUS.

and pulled along by a smaller loaded box, Q, which was suspended by a cord passing over a pulley, H. The slide on which the slider rested was supported by beams, AA (only a short length being shown in the figure), and both slider and slide could, after each set of experiments, be replaced by others of different material.

Suppose the weight of the suspended box so adjusted as to just pull the larger one along, any increase in the weight of the latter would prevent motion taking place. Morin found that if this weight were doubled, that of the suspended box must also be doubled for motion to take place; if it were trebled, the other must also be made three times as great, and so on. In short, for every pair of surfaces the force of friction (which, if we suppose the pulley to be frictionless, was directly measured by the weight of the smaller box) varied directly as the pressure between the surfaces (as measured by the weight of the larger box).

The truth of this can be demonstrated by the model before you. With a slider of pine on a pine slide—

A weight of 56 lb. requires 19 lb. to draw it along.
 " 28 lb. " 9½ lb. " "
 " 14 lb. " 4¾ lb. " "

If the two surfaces were changed for another pair, the same fact was found to hold, although the proportion between the weights had a different value. This we can also verify by changing the surfaces of pine for cast iron. The result now is that roughly:

A weight of 56 lb. requires 8 lb. to draw it along.
 " 28 lb. " 4 lb. " "
 " 14 lb. " 2 lb. " "

It is evident that, if the first law be true, there is for one pair of surfaces always a definite numerical relation between the resistance of friction (represented by the weight over the pulley) and the reaction of the surfaces (represented by the weight on the slider). The number expressing the ratio of these two quantities is called the "coefficient of friction." Thus from our experiments:

The coefficient of friction of pine on pine

$$\frac{19}{56} = \frac{9\frac{1}{2}}{28} = \frac{4\frac{3}{4}}{14} = 0.339.$$

The coefficient of friction of cast iron on cast iron

$$\frac{8}{56} = \frac{4}{28} = \frac{2}{14} = 0.143.$$

It is convenient to have a symbol to represent the coefficient of friction, and the symbol which has been appropriated for the purpose is the Greek letter μ . Also let

F = the resistance of friction.

R = the reaction between the surfaces.

Then for pine on pine—

$$\frac{F}{R} = \mu = 0.339.$$

For cast iron on cast iron—

$$\frac{F}{R} = \mu = 0.143.$$

The value of μ has been determined for all solid bodies which are likely to be used in frictional contact, and tables of results are to be found in various works on mechanical science.

Besides the method above described, there are two other ways in which the first statement of Coulomb may be verified. The former of these ways can be illustrated by means of the simple apparatus before you. In this apparatus (Fig. 2) the pine slide, AA, is

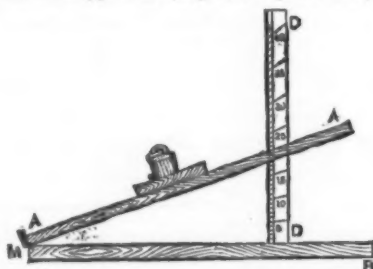


FIG. 2.—APPARATUS FOR MEASURING THE ANGLE OF FRICTION.

hinged at one end, M, to the base, B, and by gradually raising the other end, a position is reached at which the weight upon it moves down at a uniform rate under the action of gravity, which is then just sufficient to overcome the resistance of friction.

The inclination of the slide to the horizon can be observed by means of a vertical scale, D D; and if we replace the weight by others in succession, we find that as long as the surfaces are the same, the angle (ϕ) at which sliding takes place is always the same (being in this case equal to $18^\circ 45'$). This fact proves the truth of the first law of friction; for suppose G (Fig. 3) to be

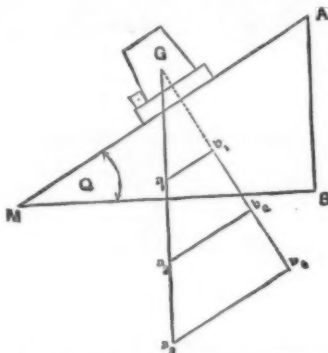


FIG. 3.—DIAGRAM FOR PROOF OF FIRST LAW OF FRICTION.

the center of gravity of the weight and slider, and Ga_1 , Ga_2 , Ga_3 to represent various weights, then Gb_1 , Gb_2 , Gb_3 represent the corresponding reactions between the surfaces in contact, and (when the slider moves down at uniform speed) a_1b_1 , a_2b_2 , a_3b_3 the corresponding frictional resistances. From the figure it is clear that—

$$\frac{\text{Resistance of friction}}{\text{Reaction bet. surfaces}} = \frac{F}{R} = \frac{a_1b_1}{Gb_1} = \frac{a_2b_2}{Gb_2} = \frac{a_3b_3}{Gb_3}$$

But, as we have already seen, the first law really asserts the ratio between F and R to be constant, and so the truth of that law is again verified.

The angle at which sliding takes place, for any pair of surfaces, is called the "angle of friction" for those surfaces, and is connected in the following simple way with the coefficient of friction. Since each of the triangles Ga_1b_1 , Ga_2b_2 , Ga_3b_3 is similar to the triangle A M B, it follows that—

$$\frac{a_1b_1}{Gb_1} = \frac{a_2b_2}{Gb_2} = \frac{a_3b_3}{Gb_3} = \frac{AB}{MB} = \frac{F}{R}$$

$$\text{Also } \frac{AB}{MB} = \tan \phi = \tan (\text{angle of friction}) \text{ and}$$

$$\tan \phi = \frac{F}{R} = \mu.$$

Thus in the case of pine upon pine—

$$\phi = 18^\circ 45' \text{ and } \tan 18^\circ 45' = 0.339,$$

which is the coefficient of friction for those surfaces.

Lastly, there is yet one other way of verifying the first law. Suppose a force to act at first vertically upon the slider, and its direction to be gradually inclined. Then at a certain inclination with the vertical the slider will just move along the slide. This angle is the same as long as the surfaces are the same, whatever be the force acting, and is, in fact, the angle of friction. Fig. 4 shows why this must be the case if the first law

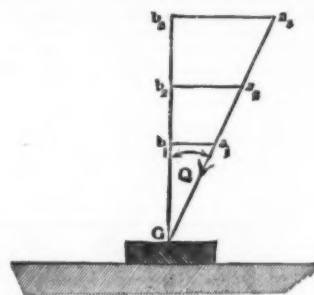


FIG. 4.—THE FIRST LAW OF FRICTION.

be true, for if a_1G , a_2G , a_3G represent in magnitude and direction the successive values of forces acting, then—

$$\frac{E}{R} = \frac{a_1b_1}{Gb_1} = \frac{a_2b_2}{Gb_2} = \frac{a_3b_3}{Gb_3} = \tan \phi$$

that is, the frictional resistance varies with the reaction between the surfaces.

The second statement of Coulomb, which is often called the second law of friction, really follows directly from the first. To make this clear, suppose the original area of the surface of the slider to be four feet. Let it be altered so as to have eight feet in contact with the slide. Then the weight of the box, D (Fig. 1), being unaltered, it is clear that each four feet of surface in contact now only sustains half the load in the box, that is to say, is subject to half the pressure it previously had, therefore for that portion the resistance of friction will be only half as much as before, and for the whole surface it will be twice as great as this, or equal to the original amount. By a similar method of reasoning, it may be proved that the weight in the smaller box would remain unchanged, whatever changes were made in the extent of the surfaces in contact, which proves the truth generally of Coulomb's statement that the resistance of friction is independent of the extent of those surfaces. We can readily verify this with both models we have used (Figs. 1 and 2) with sliders of various sizes.

It is here necessary to point out an important qualification that must be understood as attached to the above statement, which only holds true as long as the surfaces in question form one pair, the different parts of which are rigidly connected with each other, so as to distribute the reaction. This may be easily shown by means of a piece of apparatus (Fig. 5), consisting of four

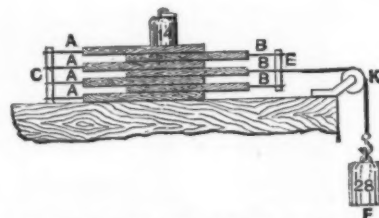


FIG. 5.—THE TRANSMISSION OF SURFACE PRESSURE.

flat pieces of wood (A A A A) alternating with three other similar pieces (B B B), the former being fastened to an upright pillar, C, the latter to a rod, E, which rod, E, sustains the pull of a weight suspended over the pulley, K. The result of this arrangement is that there are six pairs of surfaces in contact. Hence, instead of the friction remaining independent of the extent of the surfaces, it is increased by each additional surface, just as if a separate weight equal to the original one had been added. In the case before you, the weight of 14 lb. resting on the slider would, for one surface only, require $4\frac{3}{4}$ lb. to overcome the friction, whereas six times that amount, or rather more than 28 lb., is actually required.

The simple explanation of this is that pressure, instead of being distributed by the additional surface, is transmitted from one to the other. This device for increasing the resistance of friction by increasing the surfaces of contact has, as we shall hereafter see, been directly employed in a very interesting invention, and is one of many examples in which the results seem to contradict the second law of friction, but which are quite in accordance with it, in its qualified form of statement. This principle of transmitting force to increase friction is used in many cases, and is, for instance, of universal application in the employment of cords and bands for transmitting power over pulleys.

The third statement of Coulomb was verified by Morin in two ways. In one of them the two weights (Fig. 1) were carefully adjusted so that the smaller was just sufficient to draw the larger one along. Then it was found that whatever was the initial velocity of motion, this velocity was uniformly maintained. This experiment we can repeat with our own models, and it is clear that the law is, as far as can be observed, correct, at any rate for the distance which the slide can move.

In the second method adopted by Morin, a greater weight was used in the small box than was sufficient to overcome the resistance of friction, the effect being to

cause the rate of motion to increase. The rate of increase was carefully recorded, and was found always to correspond exactly to that due to the surplus weight in the suspended box. That is to say, at whatever speed the surfaces moved over each other, the resistance of friction only required a constant weight to overcome it, the excess of weight merely acting to further increase the velocity.

The simple laws of friction which we have now studied can readily be expressed in a mathematical form. We have seen that the first law is equivalent to the statement that the ratio of frictional resistance to the corresponding reaction between the surfaces is constant, and that the second law is included in the first. Now, the third law merely states that the velocity of motion has no effect on the resistance of friction, and, therefore, the velocity will not occur in any mathematical expression of the laws. Thus all three laws are completely expressed by the simple equation:

$$\frac{F}{R} = \mu$$

or, Resistance of friction $= \mu \times R$.

This expression is so simple and so convenient to use that it is not surprising that it has been universally adopted. We shall, however, see that, although the laws which it represents are approximately true within certain limits for dry surfaces, they are correct neither as regards velocity nor pressure for the range of values commonly occurring in practice, and are altogether incorrect if applied in cases where lubricants are used.

Hitherto we have considered only the case of direct sliding. We now come to the study of the rolling of surfaces over each other, the cause of the resistance to which it is not so easy to understand.

By means of an arrangement which is fitted into the lantern, we can examine the rolling of two surfaces upon each other from the enlarged image on the screen.

Fig. 6 shows three pairs of disks, each pair of which is actuated by an arrangement similar to that shown in ii, the wheel, A, driving the lower disk by means of the screen.

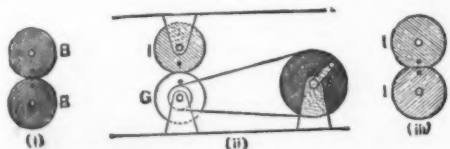
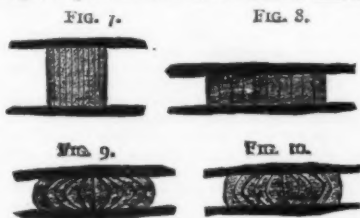


FIG. 6.—LANTERN APPARATUS FOR INVESTIGATING ROLLING FRICTION.

a fine endless band, the lower disk in turn imparting motion to the upper one by the frictional contact of their edges. Taking first the pair of brass disks, BB (i), it is seen that although they are pressed together with some appreciable force by means of a spring, the extent of contact is extremely small; indeed, they scarcely seem to touch at all, yet when the lower one is turned, the upper one is carried round, and no apparent slipping takes place. This is made evident by the aid of two small holes drilled in the disks, which, being placed initially so as to be opposite each other, are seen to occupy the same relative position after every revolution, even when the speed of rotation is considerably increased. If we now examine the rolling of the two India rubber wheels, II (iii), we find that the extension of the edges under the pressure causes a greater area of contact, but that the force required to rotate them is not increased so much as might be expected. The fact is that, being equally soft, the extension of their peripheries is equal, and thus there is no appreciable slipping of their surfaces upon each other, which is evident from several observations of the relative positions of two holes made for the same purpose as those in the brass disks. Lastly, let us examine the rolling of a hard surface and a soft surface upon each other. This we can do by the glass wheel, G, Fig. 6 (ii), with roughened edge working on an India rubber wheel, L. Here we can see that the India rubber edge is extended so that the area of contact is, as in the foregoing case, considerable. The result of this extension is to cause the rolling periphery of the India rubber to be greater than that of the glass; and if we now compare the relative position of the spots of light passing through the holes in the two disks, we see that the India rubber disk, being practically larger than the glass one, turns at a slower rate. The resistance to turning, which is appreciably greater than in the first of the two foregoing cases, and, as far as can be judged, if anything, greater than in the second, is accounted for by the fact that the surface of the India rubber must, in extending, slip over the harder surface in contact with it. This is the cause of what Prof. Osborne Reynolds has rightly insisted should be called rolling friction (the word friction being derived from a Latin word signifying "to rub"), and he has explained the action which takes place in a very interesting way.

Let Fig. 7 represent a block of elastic material held



THE FRICTION OF SURFACES IN EXTENDING AND CONTRACTING.

between two surfaces which are capable of being pressed together. Suppose first that there is no frictional resistance between the block and the surfaces. Then the result of compressing the block will be simply to cause it to take the form shown in Fig. 8, the series of vertical lines being shortened and moved further apart. Suppose, however, that there is some appreciable friction,

then the lines originally vertical will be caused to curve to a greater or less extent, as shown in Figs. 9 and 10. Fig. 9 represents the case where the frictional resistance is small. Here the effect of the compression is to cause all the surface to slide, except that portion between the two darkened lines (originally vertical) on either side of the center line. Fig. 10 represents a case where the friction between the surfaces and the block is greater than in the former case. Here slipping takes place only at the third lines (shown thicker than the rest in the figure) on either side of the center line.

We can examine different cases of frictional resistance by means of an arrangement which is now projected on the screen. Fig. 11 represents a portion of a frame (F)

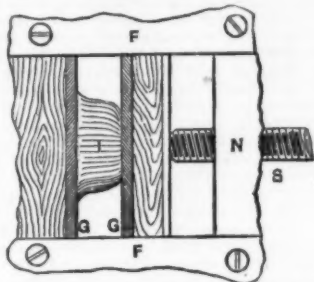


FIG. 11.—LANTERN APPARATUS FOR EXAMINING SURFACE RESISTANCE TO EXTENSION AND CONTRACTION.

F, in which a screw (S) works in a nut (N), and enables a pressure to be brought upon a sliding piece with a thick glass plate (G), between which and another thick glass plate, G (fixed to the frame), a block of India rubber (L) is placed. The action which goes on can thus be carefully studied, not only for the glass surfaces, but for surfaces of any other kind which can be inserted between the glass and the India rubber. Fig. 11 shows the result of having a dry clean surface of glass on the moving side, while the surface of glass on the fixed side is slightly oiled. Time does not permit me to dwell on the various results I have obtained with different surfaces, particularly in the form of the outline of the block under pressure, but they do not appear to be included under what Prof. Reynolds has mentioned in his paper.

Now, the work done in overcoming the resistance to sliding cannot be restored when the surfaces are again separated. To realize this important point, it must be remembered that the lateral extension would be greater but for the frictional resistance to sliding, and the work now done in friction would otherwise store up an equivalent amount of energy to be given up by the return of the block to its original form. In the same way the block, in returning to its original shape, has a certain portion of its power of restitution absorbed in overcoming frictional resistance. Thus there is a loss of energy both in the extension of the surfaces and in their compression. It is evidently a matter of the greatest consequence to see whether this takes place in the rolling of two surfaces on each other. We may investigate this point in the following way: Make two marks tolerably close to each other on the rim of a soft disk rolling on a hard one (e. g., the India rubber on the glass disk, Fig. 6, ii), and take the distance apart of these with a fine pair of compasses or dividers. Keep the one leg of the dividers upon one point and roll the disk so as to bring it into the line of contact, noting meanwhile the change of distance of the other point from it. Then it will be found that both on approach and recession to the line of contact, the sliding friction acts in the opposite way to the motion of rotation, i. e., acts as a retarding force.

Let us now consider the actual magnitude of this resistance and the work lost in rolling friction. In the first place, it is clear that the extent of this loss does not depend only on the roughness of the surfaces in contact, for reverting to Figs. 9 and 10, the distance through which slipping takes place is greater in the former case, although the sliding frictional resistance is less, and we cannot tell without an experiment in which of the two cases the total loss is the greater. Thus we cannot say without a trial whether a gain or a loss results from oiling or blackleading two surfaces which have to roll on each other. As Prof. Reynolds has pointed out, between the two extreme cases of no frictional resistance and definite extension on the one hand and infinite frictional resistance, which allows no slipping to take place, on the other (in either of which cases no work at all is expended in friction), there must be some point where the maximum of energy is lost. We have not yet arrived at any theoretical method of determining the amount of rolling friction for various substances, and must obtain results by direct experiment. We have before us a piece of apparatus which I have devised for roughly exhibiting to you how this can be done, and at the same time further illustrating the foregoing views.

Fig. 12 represents a stand, A A, upon which surfaces

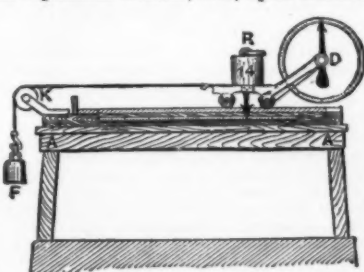


FIG. 12.—APPARATUS FOR INVESTIGATING ROLLING FRICTION.

of various kinds can be placed, and over these surfaces a truck, moved by means of a weight (F) suspended over a pulley (K). The rollers of the truck can be

changed for others of any required material, one of them having a pulley which by means of an endless band turns a pointer (D), thus recording on the large circular dial the extent to which the roller turns. The dial itself is fixed to the frame of the truck, and also another pointer which records on a horizontal scale the distance through which the truck moves. We have now upon the truck a weight of 14 lb., and we will make four experiments, the first two with India rubber rollers, first on wood and then on an India rubber surface, and the last two with rollers of hard wood, on wood and India rubber as before. In each experiment the truck is drawn through the same distance as shown by the horizontal scale, but from the readings on the circular dial it is evident that the rollers turn to a rather different extent in all four experiments. The following is a table of the results:

No. of Experiment.	NATURE OF SURFACE.		Weight over Pulley (F)	Reading of Circular Dial.
	Roller.	Path.		
1	India-rubber	Wood	10 oz.	0.44
2	"	India-rubber	9 1/2 oz.	0.42
3	Wood	"	6 1/2 oz.	0.3
4	"	Wood	5 1/2 oz.	0.25

These results accord pretty fairly with the views set forth as to the nature of rolling friction, except that it might seem as if, in the matter of frictional resistance, the second and third experiments should change places. It should, however, be mentioned that the India rubber of the roller and that of the path are of different degrees of hardness and pliability, obviously resulting in more frictional resistance than would be the case if they had the same properties.

From reasoning and experiments of this kind we arrive at clear ideas of the nature of the resistance to rolling; and although we cannot actually see the deformation which takes place at the point of contact of the surfaces of hard elastic bodies, yet we know that temporary deformation does take place, and we may conclude that this resistance is in all cases caused by the sliding of the surfaces in contact over each other. Hence we shall not be surprised to find that the laws of rolling friction set forth long ago by Coulomb, and determined by experiment, are identical with the simple laws of sliding friction, with the simple addition of the statement that the resistance at the center varies inversely as the radius of the rolling body. The laws in a mathematical form are therefore simply:

$$\text{Frictional resistance} = F = \mu \frac{R}{r}$$

Whereas before,

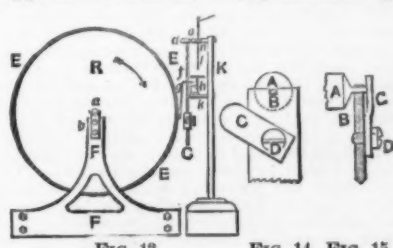
μ = coefficient of friction, determined by experiment.

R = the load on the roller.

r = the radius of the rolling body.

The somewhat artificial idea, used by Coulomb and adopted since by other writers, of an imaginary arm, which, multiplied by the load, gives the moment of friction, does not seem to be necessary, and certainly does not assist in making the action of rolling more easy to understand.

The general laws concerning the rolling and sliding of solid bodies which have now been given are for many purposes sufficiently correct. It has long been known that the laws of Coulomb must only be regarded as convenient approximations to the truth. For dry surfaces (with which only we are concerned in this lecture), the first law, and therefore, by implication, the second, is practically accurate. When, however, the pressures are very great, and, as in the experiments upon railway brakes, abrasion takes place, Captain Douglas Galton found that the coefficient of friction diminished for some little time after the pressure had been applied. Various suggestions as to the cause of this were made when Captain Galton's paper on "Brakes" was being discussed, such as the formation of a film of air, the action of the heat generated, etc., but whatever be the explanation, the circumstances are evidently abnormal, and for all normal conditions the first and second laws may be supposed to be correct. The third law has been examined both for very high and very low velocities, and for the latter, when the surfaces were tolerably hard, has been found to be absolutely correct. The apparatus by which Messrs. Jenkin and Ewing arrived at this result, and by which they obtained other results which we shall have occasion to allude to, consisted of a cast-iron disk, R (Fig. 13), supported on a frame, F F, by means of a spindle,



APPARATUS OF JENKIN AND EWING FOR INVESTIGATING FRICTION AT LOW VELOCITIES.

a, turned down to a very small diameter to work in a bearing, b. Figs. 14 and 15 show two enlarged views of the bearing and spindle, the former being square in section, and also a plate, c, acting to prevent any end play of the spindle. A strip of paper, E E, is fastened round the edge of the disk, which is then set in motion, and continues to revolve until the friction of the spindle in the bearing brings it to rest. During the time that it is gradually coming to rest, the pendulum,

C, moves to and fro at right angles to its plane of rotation, and causes a continuous curve to be drawn on the paper band by means of a siphon recorder, K. Fig. 16 is a portion of the record thus obtained, and it can be seen how the wave length of the curves—at first considerable—gradually diminishes, and at last, at the point, P, the disk comes to rest. By analyzing

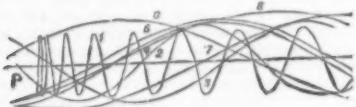


FIG. 16.—CURVES TRACED ON EDGE OF ROTATING DISK.

the curves, the law connecting the resistance of friction with velocity, at speeds as low as 0.0002 foot per second, was obtained, with the result already stated.

The exact laws connecting the velocity and friction at high speeds are not known, but it is certain that the friction invariably diminishes at high speeds.

The simple laws of friction are thus sufficiently accurate for dry surfaces to enable them to be relied on in the solution of various mechanical problems. An important example in which this is done is in the determination of the power which can be transmitted by the frictional contact of a rope or belt over a pulley. In this case it is evident that the force transmitted is the difference in the tension of the belt on the two sides of the pulley. Now, reasoning upon the simple laws of friction, it may be proved that ratio of less tension to the greater

$$\frac{S}{T} = \frac{1}{10^{-0.075} \mu \theta}$$

where μ = coefficient of friction (which for leather on cast iron = 0.42)

θ = angle embraced by the belt.

From this it follows that difference of tension on the two sides, which is equal to the force transmitted

$$= F = T (1 - 10^{-0.075} \mu \theta)$$

The action of the belt in passing over the pulley is precisely the same as that explained to take place in the rolling of bodies on each other, the belt, in point of fact, rolling on the pulley. The phenomenon of the slipping which takes place in consequence of the temporary extension of the belt is known as the "creep" of the belt, and involves a loss of from 1 to 2 per cent. of the whole power transmitted. By a similar mode of reasoning, the frictional resistance of coil of rope, the traction of wheels on elastic surfaces, and other problems, may be dealt with.

So far, the surfaces of the solids we have been considering have been of appreciable magnitude, and we have dealt with the friction taking place between one pair of surfaces only. We must now proceed to consider the frictional resistance which results from the contact of many surfaces where the area of contact of each is very small, and where we cannot examine the frictional resistance of each, but only the aggregate effect.

1. Such a case is the frictional resistance afforded by substances composed of a number of parts not cohered together, such as earth, sand, and grain.

2. Another case is the friction between the parts of a fibrous material, such as rope, which we know is caused by the action of the separate parts upon each other.

3. Finally, we have the action which takes place in solid bodies when any change of form, however slight, takes place, and which we have strong grounds for believing is of the nature of friction between their ultimate particles.

If we observe a mass of dry earth, sand, or any granular substance, we shall see that the sides, if not artificially supported, have a certain inclination to the horizon, and that though this inclination is uniform for any one material, yet it differs for different materials. We can, by means of an arrangement in the lantern, examine this upon the screen, and you will see that, whatever form I initially give any substance of this kind, its sides invariably assume a particular inclination.

This inclination is called the "angle of slope," or "angle of friction," of the substance, and is of great importance, being, in fact, the sole basis of existing theories by which such important problems as the pressure of earth and sand on retaining walls, tunnels, arches, etc., are dealt with. It is beyond our province to enter into the details of the reasoning by which the mathematical results are obtained, but it is an undeniable fact that the engineer, though employing them as a guide in general principles, does not rely upon the exact numerical results obtained by calculation, but allows a very large margin for the uncertainties of the case. For instance, the pressure on a vertical retaining wall is, by theory, merely due to the weight of material between the back of the wall and the plane bisecting the angle of complement of the angle of slope. This is simple enough to understand, and upon it the numerous tables of pressures are calculated; yet the greatest authorities have recently stated in a public discussion that the retaining walls they built gave them more anxiety than any other kind of structure, and their conviction of the general supremacy of practical over theoretical considerations in such cases. The explanation of this seems to be that it is not merely the frictional resistance that acts in the case of earthwork, but the cohesive action due to the varying hygrometric state of the mass, and that it is only the judgment obtained by long practical experience which can be relied upon to form a correct estimate of the conditions of the case. Still, the failures in retaining walls do not appear to have been caused so much by a miscalculation of the pressure of the earthwork as by the failure of the foundations of the walls. A very high authority* recently stated that ninety-nine out

of one hundred cases of failure are due to the latter cause.

As far as the action of the parts of a perfectly dry granular substance on each other, recent investigators have established the fact that the "historical" element must be carefully taken into account; that is to say, the effect of individual particles upon each other must be considered, and not merely their aggregate effect, even though we may not be able to examine the individual surfaces separately. Thus, in the behavior of a mass of sand or grain, not merely the frictional resistance of the surfaces of the grains, but also their shape, must be considered. Professor G. H. Darwin, of Cambridge, and Mr. Isaac Roberts, of Liverpool, have independently, and by means of different experimental apparatus—the former working with sand and the latter with corn, peas, oats, and other grain—arrived at very similar general conclusions and results. Both these gentlemen found that the grains apparently built themselves into the form of eccentric arches, with their concavity toward the side on which the pressure was relieved, so that the pressure was considerably diminished from this cause; moreover, that the initial position was unstable, and was caused by the irregular distribution of the grains, a certain amount of shaking or vibration causing the grains to fill up the interstices by a process of "settling." This amount of settling (which, curiously, in all cases, appears from an examination of the figures to have been about 10 per cent.) resulted in a rearrangement which caused a greater internal coefficient of friction, and, therefore, reduced the pressure on the sides.

The object which Mr. Isaac Roberts had in view was to directly determine the pressure of grain stored in elongated cells or "bins." In America this method of storing is largely adopted, bins being used from 10 ft. to 12 ft. square, and from 50 ft. to 80 ft. high. In this country their adoption is quite recent, and it was because of the absence of the data needed in their construction in Liverpool that the experiments were carried out.

The first set of experiments was made with comparatively small wooden bins, the largest of which was 96 inches high, with hexagonal cross section, the inscribed circle of which was 20 3/4 inches in diameter. As the grain was gradually poured into the bin, the pressure on the movable bottom was registered by means of a suitable device, and the astonishing result transpired that in all cases this pressure entirely ceased to increase at some point before the depth of two diameters was reached. From a comparison of the pressures and corresponding heights, Mr. Roberts concluded that this was due to the fact that the grains formed "a self-supporting parabolic dome held in position by friction." Further experiments were made with bins of larger size, the lateral as well as the bottom pressures being obtained by means of the weighing apparatus (Figs. 17 and 18), both these machines being

FIG. 17.

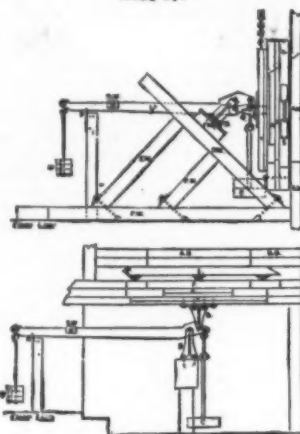


FIG. 18.

APPARATUS FOR TESTING THE PRESSURE OF GRAIN.

capable of weighing, with great accuracy, from one pound weight up to 1,800 lb. Fig. 17 shows the machine for weighing lateral pressures, Fig. 18 that for bottom pressures, both being arranged to measure the effect on areas of 1 sq. ft., 4 sq. ft., and 9 sq. ft.

The final conclusions arrived at by means of a number of experiments, in which the depth of grain was gradually increased to a depth exceeding 50 ft., quite confirm those of the first set of experiments. The results for bottom pressures are expressed in the following manner:

Let a = cross section of column of grain in sq. ft.
 d = diameter of inscribed circle in ft.
 w = weight of grain in lb. per cub. ft.
 c = constant, determined by experiment.
 Then if p = pressure upon the bottom in lb.
 $p = a \times d \times w \times c$

Now for wheat $c = 0.84$, for peas $c = 0.96$, and if the value of unity be adopted, the margin will be on the safe side. Then the expression will finally stand:

$$p = a \times d \times w.$$

The lateral pressures cease to vary after a height three times the breadth of the aperture is reached, and may be considered constant per unit of area at any point of the bin above that height. The value of this pressure for all grain may be estimated at 50 lb. per square ft. Mr. Roberts, however, recommends that in actual construction the calculations of the strength of any wall or partition should take four times this value, or 200 lb. per square ft.

2. We have already considered the friction on the external surface of ropes and bands, and we must now study the friction which takes place between the separate parts of which such substances are made. This friction is of considerable importance in questions of transmitting power, since much work is lost in the use of ropes and stiff leather belts, from the continuous

bending and unbending which takes place in passing round a wheel or pulley. Indeed, this fact has led to the invention and introduction for collieries of a special form of wire rope, the resistance to the bending of which is much less than with the ordinary form.

The rigidity or resistance to bending of ropes was investigated by Coulomb by means of the arrangement shown in Figs. 19 and 20. A loaded platform, Q,

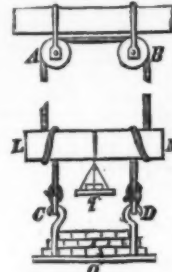


FIG. 19.



FIG. 20.

APPARATUS OF COULOMB FOR INVESTIGATING THE RESISTANCE OF ROPES TO BENDING.

was suspended from a beam by being attached to the two ends, C and D, of a rope. This rope passed over two pulleys, A B, fixed to the beam, thus equalizing the pull in the two portions, which were each wound once round a cylinder, L M. The frictional resistance of the rope to bending was then measured by having a smaller loaded platform, q, suspended from the outer edge of the cylinder, as shown in Fig. 20. The results of these experiments showed that the resistance to bending depended (1) on the nature of the rope; (2) on the force transmitted; (3) on the extent to which the rope was bent, the rigidity (B) of the rope being represented by the expression—

$$B = \frac{a + b P}{r}$$

where a and b are two constants, depending on the nature of the rope, and P and r are respectively the force transmitted and the effective radius of the pulley and rope. Thus, with a rope 1 inch in diameter, raising a weight of half a ton over a pulley 1 foot in diameter, there would have to be an extra force applied of more than 50 lb. in order to bend the rope.

When a rope passes over a single pulley transmitting some appreciable force, the resistance to bending causes the rope to be deflected outward from the direct line of approach, so as to come into contact with the pulley rather later than it otherwise would. A similar effect is observed as the rope is leaving the pulley, but now it is bent inward from the line of recession, and there is consequently a larger area of contact on this side.

The amount of this deflection is much greater in the former than the latter case, and is, according to Eytelwein (quoted by Cotterill):

$$x = c d^2$$

where d = the diameter of rope in inches
 $c = 0.47$ for hemp ropes.

This, however, is only correct for small pulleys and light roads. For leather belts the resistance, though appreciable, is of uncertain amount, and is usually neglected.

Although we have regarded the friction between the fibers of a rope in its prejudicial aspect, we shall see in the third lecture that it is this internal friction which enables rope and fibrous materials to be manufactured; but I will not at present say more on this subject.

3. We have now to consider the action which takes place between the internal parts of solid bodies. When a rope is bent, we can readily account for the sluggish manner in which it tends to partially return to its original shape, by conceiving that it is only gradually that the elasticity of the individual fibers can overcome the internal resistance acting between them. The frictional resistances to change of form are in this case easy to understand and trace. Not so, however, can we reason with regard to the case of homogeneous solids. We do not know the nature of the forces binding the ultimate parts together, and we cannot at first say whether the resistance to change of form may not be entirely due to some force of attraction, or whatever else the so called resistance of cohesion may be, especially in the case of bodies which, when slightly distorted, return exactly to their original form.

Unless, however, we are to assume that the ultimate parts are themselves elastic bodies capable of change of form, we must admit that every change of form of the solid must be accompanied by relative motion of its parts over each other. The question then naturally arises. Is there anything in the behavior of solid bodies under the action of stress analogous to the behavior of fibrous bodies? Many years ago Sir William Thomson measured the extension of copper wires for gradually increasing loads suspended from them, and then measured the amount of contraction which occurred as the loads were gradually removed. He found that although the copper wire returned to its original form when all the weights were removed, yet its length during contraction did not agree with that during extension for corresponding weights. Thus, since its elasticity was perfect, there must have been, over and above the mere tenacity of the wire, some resistance to change of form occurring, doubtless, both in extension as well as contraction, the nature of which corresponds to the friction between the fibers of the bent rope.

There are a large number of physical facts which point to the same conclusion; such, for instance, as the creaking of tin; but the most striking evidence is derived from the facts which support the mechanical theory of heat. Suppose the surfaces of two solids placed in contact and rubbed over each other until, by the removal of projecting portions on each, they become smooth, and that there is then no appreciable wearing away of either. When this stage is reached, work has still to be expended in maintaining their relative motion, and this work is now known to have

* Mr. Benjamin Baker, in his paper on "The Actual Lateral Pressure of Earthwork" (Min. Proc. Inst. C. E., vol. lxx., p. 140, to which paper and the discussion thereon readers are referred for much practical information on the subject.

its exact equivalent in the heat produced. We believe that the friction of the particles over each other sets up molecular motion, which is communicated by internal friction throughout the whole mass. No theory in physical science has led to more important results than this, and none rests on a more sure foundation, so that we need have no hesitation in considering that the resistance to change of form, as, for instance, in bending a metal bar, which results in the production of heat, is due to the same cause as the surface resistance.

We have now examined the chief facts in the friction of solid bodies, and we see that the resistance, whether external or internal, is simply due to the same cause, viz., the rubbing of the individual molecules over each other. Further than this we cannot at present go, for when we know definitely what the nature of this molecular motion is, we shall have solved the great problem of the constitution of matter itself.

Thus I hope that the answer to the question which is put from time to time, viz., What is friction? has, in the case of solid bodies, been made clear, so far as an answer can at present be given.

In conclusion, we may show that all the facts we have discussed are thus accounted for, at any rate so far as the point to go further than which would involve a knowledge of the molecular constitution of matter, and at which point we must for the present be content to stop. These facts referred to all resolve themselves into the first law of friction (which includes the second) and the third, with the rider to the latter, that at very high velocities the friction somewhat diminishes.

Now, many writers have thought it necessary to propound a special theory of the physical constitution of the surface of bodies to account for the laws of friction. This theory is that the surfaces are serrated like the teeth of two saws which fit into each other, and that it is in raising the upper body up as each tooth is passed that the work of frictional resistance is expended, the deeper the serrations the greater being the frictional resistance.

A writer in a scientific journal, in an article* on "Friction," has gravely attributed the musical (?) note which bodies sometimes make in frictional contact to the direct action of these grooves, and has proposed to calculate the coefficient of friction from the number of vibrations. I will produce with this stick of wood a note (which whether musical or not is a matter of taste), and I do the same thing five times across a piece of ground glass which I now place in the lantern, and you will see (Fig. 21) that I ought, from the marks produced,

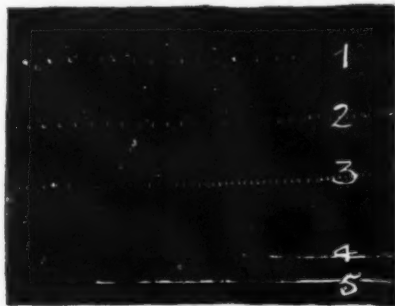


FIG. 21.—AUDITORY EFFECTS OF FRICTION.

to have had five different musical notes, and five (or from the figure more probably fifty) different coefficients of friction. I need scarcely say the musical note was the same, because I used the same stick of wood, upon the length of which alone depend the longitudinal vibrations set up within it which give the note emitted, the note having nothing whatever to do with the number or distance apart of the imaginary serrations.

The theory of serrations has been so often propounded and supported by arguments and by calculations, that it must be briefly considered. There is no need to enter into the arguments in its favor, since there are two fatal objections against it.

One is that for smooth bodies it is perfectly impossible by any optical means we possess to detect any such serrations, or even minute raised portions, on the surface—the body can thus only be raised through a distance exceedingly minute—therefore, in order to obtain the equivalent of the work done, the body must be raised through this minute distance with a frequency such as to cause the velocity of motion to be very great. The kinetic energy generated at each rise of the body, however, varies as the square of the velocity imparted to the body, and by taking any special case and making a calculation, it at once becomes evident that the theory cannot be maintained. The other objection is still more obvious. In propounding the theory, a sketch is usually given of a section of the serrated surfaces, which are assumed to have parallel grooves. Now, this is altogether inadmissible, for what projections there are must be distributed more or less uniformly over the entire surfaces, and the idea of any falling into grooves cannot be seriously entertained.†

* *Mechanical World*, December 11, 1885, p. 421.

† Since this was written, a paper has been published in the "Minutes of Proc. Inst. C. Engineers," vol. LXXV., p. 376, on "Recent Researches in Friction," read at a meeting of the students (November, 1885), by Mr. John Goodman. The paper, after giving an interesting account of experiments on friction, proceeds to a theoretical consideration of "Dry Friction," which is said to be of a much more complex nature than that of lubricated surfaces (with reference to which statement vide Lecture II.). The author supposes the nature of the surfaces of all solid bodies to resemble in structure the surface or "pile" of velvet, there being always some pile left, however smooth the surfaces may be worn. The physical properties of the material determine the "pitch of the pile," or number of piles per unit area. He then goes on to discuss, by means of diagrams, the effect of such a surface with the usual tacit assumption of grooves parallel to each other, and perpendicular to the plane of the paper. The work done in frictional resistance is supposed to be simply that required to raise the body each time it falls the depth of the pile, the fall generating the heat of friction. A formula is given for the amount of this work, which is of the form—

$$\text{Work} = \text{number of piles} \times \text{depth of pile} \times \text{weight of body}.$$

Various facts, such as the increased resistance upon reversal of motion, the smaller coefficient of friction obtained with dissimilar than with similar metals, and the existence of the angle of friction, are explained with the aid of diagrams. Several of the points assumed are open to very obvious objections, to which it is hard to see an answer; but it will be

The simple explanation of the first law of friction seems to be this: Supposing the surfaces to be smooth and worn to their normal condition, there are even then only a certain very limited number of points in contact (*vide* the best surface plates), and further wear merely removes groups of particles, leaving other hollows, or, if no wear is taking place, merely pushes down, or on one side, the projecting particles. Any increase of pressure brings a larger number of particles into contact, and so increases, to a proportional extent, the friction, or amount of rubbing and consequent heat produced. Hence the friction varies with the pressure. For low velocities, the constant resistance simply depends on the number of particles in contact, and, as this at any point is the same, the friction is not altered; when, however, the velocity is very high, it may be that the surfaces are slightly separated, and the friction is thereby reduced; and it may also be that prominent particles, periodically displaced, but not permanently removed, may not regain their position so rapidly as to interfere with as many particles on the other surface as they otherwise would.

I trust you will now realize that it was necessary, in order to make clear the connection between the various facts in the friction of solids, and to give a logical explanation of these facts, to discuss at length the time honored laws of friction. We have, however, treated of only one phase of the nature of friction, others being reserved for the next lecture.

(To be continued.)

REMOVAL OF STEAM FROM DRYING MACHINES.

BESIDES being the season of fires, as is frequently observed, the present is the season of fog and vapor in our atmosphere. This is owing to the evaporation of moisture from the earth's surface caused by the unexhausted heat stored up in summer. This vapor, rising into a cold atmosphere, is immediately condensed,

will prove to have become infected with mildew. These and many more evils we have not space to enumerate, but which have been—and are even still—the trouble of manufacturers, may be obviated by employing the mechanical appliances for securing ventilation that have been introduced into the market during the past year or two.

The accompanying illustration represents an ordinary drying machine for cotton fabrics, over which is a wooden hopper or hood leading into a square vertical trunk or shaft—also of wood—terminating outside the roof in a lowered turret. The hopper and vertical trunk are for the purpose of confining and carrying off the steam produced from the wet cloth in its passage over the heated cylinders; and in order to facilitate this, and, in fact, make the getting rid of the steam an absolute certainty, a 24 in. Blackman air propeller is fixed horizontally (*i. e.*, with the driving spindle vertical) at the apex of the hopper, where it joins the base of the vertical trunk. (We are assuming that the Blackman air propeller is well known to our readers by this time, and therefore confine ourselves in this article to the description of a special application thereof.) The propeller is driven by belts from a pulley on the line shaft shown alongside the wall. The base of the wooden hopper is brought down as low as it is possible to bring it without causing an obstruction, and is also kept close in line with the outsides of the steam cylinders, the object of this being to reduce to a minimum the area through which a portion of the air of the room must necessarily pass to feed the propeller when running. The propeller can be run at a speed of about 800 revolutions per minute, and at this speed it passes 6,500 cubic feet of air per minute. The air is drawn in round the case of the hopper, and in its passage to the propeller carries up all the steam which rises into the hopper from the wet cloth beneath. The mixed steam and air are then driven up the vertical trunk and discharged outside. There is no perceptible vibration from the propeller, owing to its extreme lightness, nor any noise, such as would inevitably be



THE BLACKMAN VAPOR PROPELLER IN A DRYING ROOM.

and, in a still condition of the atmosphere, forms fogs, which are so troublesome in the late autumn months.

The conditions that induce this state of things are also very troublesome in various branches of the textile industries, particularly in sizing rooms, drying rooms, and other places where steam or vapor is given off freely into the atmosphere. When the atmosphere is naturally saturated with moisture, and can absorb no more, or when there is a sharp frost, which quickly condenses the vapor being set free, it is almost impossible by ordinary means to keep the workrooms free from an injurious amount of the condensed steam. The mischiefs resulting are very serious. The ceiling, the walls, and the framework of the machinery get covered with water, which often takes up oxide of iron, and, falling upon the material, makes a stain that cannot be removed by ordinary processes. A steam-laden sizing chamber often leads to imperfect drying of the warps, and hence when they come to be woven down

sufficient to dispose of the theory of the equivalence of the work done in raising the body and that actually occurring in frictional resistance. Some time must be occupied in the rising and falling of the moving body. Let us consider that occupied in falling; and suppose this to occur under the action of gravity alone, that is, assume (as in Morin's experiments) only the weight of the body acts. Then the time in falling will have a definite amount, viz.:

$$t = \sqrt{\frac{2k}{g}}$$

(Where k = the depth of the pile.)

Now, in the first place, an obvious difficulty in the way of accepting the theory arises from the fact that unless the body fell instantaneously it must fall to a different height for every velocity, depending upon the point where, from its trajectory, the respective parts of the slanting sides of the projections or piles come into contact. Captain Douglas Galton, to account for the decrease of friction at high speeds, did, in fact, suggest the idea that the contact occurring between different parts of projecting portions at high and low velocities arose from such a cause (*vide* "Proc. Inst. Mechanical Engineers," 1879, p. 194). But this reasoning would lead us to expect a difference in friction at all velocities, which we do not find to be the case.

Beyond this, however, and without considering the nature of the outline of the imaginary projections, it may be proved by taking values far beyond those which could possibly obtain, and calculating an imaginary case, that whatever the form of the sides of the projections, the body could not possibly fall the whole depth of the pile, even at a velocity of, say, 1,100 of a foot a second, and that above this speed the resistance of friction must depend directly upon the velocity of motion, whereas at speeds many hundreds of times as great as this quantity, no difference whatever has been detected.

produced by a blast fan. The power required to drive the propeller is very little—half a horse power.

Many of our readers will be familiar enough with the evils of steam accumulation in both cotton and paper drying processes, and the loss and damage to goods occasioned by condensation of the steam and consequent drip from the roof or hopper on to the paper or cloth on the machine beneath. There is, also, the gradual destruction of the roof through the rotting of the timbers, resulting from the constant action of the steam, and it is by no means an infrequent occurrence for a drying room roof to have to be entirely renewed from this cause alone. The greatest difficulty in getting rid of the free steam is experienced in heavy, damp weather; but there are many other causes which hinder its free escape in all states of the weather, and each building is subject to quite different local conditions and influences. The patentees of the Blackman air propeller claim for it that it will absolutely clear away all steam in any state of the weather, and that its action is as positive as that of a force pump, and independent of any outside influences whatever.

We understand that many firms of bleachers, dyers, and paper manufacturers, both in Lancashire and elsewhere, have already adopted the "Blackman" with uniformly satisfactory results.

Through the courtesy of Messrs. D. Constantine & Son, we were enabled to see an application of the "Blackman" identical with that shown in the illustration at their bleach works at Breightmet, near Bolton, and we were assured by the owners that they have now no trouble whatever with steam from the drying machine to which the "Blackman" is applied, there being now no accumulation possible, and it being rarely that any trace of steam is visible at all in the hopper, and of course with the absence of steam there is no condensation, whereas prior to the adoption of the "Blackman" they frequently suffered damage to cloth and other fabrics from the drip from the hopper.

A point which we should not omit to mention is that the drying process is greatly accelerated by the "Blackman," the quantity of the output being much increased at all times, varying with the weight of the goods. The patentees also inform us that several hoppers or hoods may be connected to one propeller,

in paper machine rooms the discharge is usually horizontal through one side of the hood.—*Textile Manufacturer.*

WHITE LEAD MILL.

THE raw white lead is first ground, moistened with water, to reduce it to a powder. The usual method consists in grinding it between millstones, the lower one of which is fixed, while the upper one revolves on a vertical spindle, as in a corn mill. The lumps of white lead, previously soaked in water, are introduced by the operative into the central eye by means of a trowel, and the ground material issues at the periphery in a heated state, and falls into an open receptacle surrounding the lower stone, in which the attendant moves it by a strickle to a chute delivering the lead into a reservoir below. The fumes from the heated lead are specially injurious and annoying to the workmen employed. This inconvenience has been obviated by Mr. Carron by surrounding the millstones with a hermetically closed casing and attaching a scraper to the revolving top stone, which conducts the ground material to the chute, through which it falls into a receptacle also hermetically closed. This arrangement has been in use for two years, with the best results, and can easily be rigged up by any manufacturer, not being the subject of a patent.

The subsequent grinding with oil is generally accompanied by a considerable number of manipulations in transferring the white lead or paint from one machine to another. The process usually consists in mixing the material previously ground with water in a mixing machine, then giving it a preliminary grinding by granite edge runners, transferring it to the finishing or lustering mill, and finally putting it into barrels or cans. The

ordinarily used, and saves all the labor required for carrying the paint from one to the other, while, at the same time, consuming less power. The mill with two rolls, as described, produces, according to the *Revue Industrielle*, regularly 225 kilogrammes of finely ground white lead per hour, while older mills with four rolls in the same works turn out only 75 kilos. of less regular quality. One man suffices for working the apparatus, and the risk to the health of the operatives resulting from the manipulation of the paint is greatly reduced. From the central compartment, F, the paint is drawn off directly into barrels or cans for sale.

MEASUREMENT OF GOLD AND OTHER MINUTE METALLIC SPHERES.

By G. A. GOZDORF.

IN making assays for gold where the amount of gold is very small, a little silver is required in which the gold may be collected. As nearly all commercial litharge contains silver, it is rarely necessary to add any separately for this purpose. The litharge I at present use contains at the rate of 6 dwt. of silver and $\frac{1}{4}$ of a grain of gold per ton.

Having obtained a prill in which the amount of gold is a third or less than the silver, the prill is boiled in dilute nitric acid in a porcelain capsule to dissolve the silver, and where the amount of gold is more than 1 dwt. to the ton, a second boiling in strong nitric acid should be given. If care is taken in using dilute acid at first, and boiling gently, the gold will be left in one piece of a nearly black color. The acid is now decanted off and the gold washed two or three times in distilled water. The gold may be now placed on an aluminum or other polished metal plate by inverting the

Borax and other fluxes are so fluid when hot that the gold is very liable to alloy with the platinum wire. This rarely occurs with boracic acid on account of its great viscosity, even when white hot. Boracic acid is also easily soluble in water, so that the gold spheres can be separated without loss of time.

The following rules and figures may be useful to any one wishing to adopt the system here described.

1. The weight of a sphere increases as the cube of the diameter.
2. The weight of a sphere of any substance of which the specific gravity is known is obtained by multiplying the weight of a unit sphere of water by the specific gravity of the substance and the cube of the diameter.

Constants for Use with Gramme Weights.

1. Weight of a sphere of water 0.01 mm. in diameter = 0.000,000,000,523,6 of a gram.
2. Weight of a sphere of gold 0.01 mm. in diameter = 0.000,000,010,210,2 of a gram.
3. Weight of a sphere of gold 0.0x mm. in diameter, $x^3 \times 0.000,000,010,210,2$ of a gram.
4. If 20 grms. of ore are taken for assay, the number of grains of gold per ton is found by $x^3 \times 0.008,004$, in which x = the diameter of the sphere of gold in hundredths of a millimeter.

Constants for Use with Grain Weights.

1. Weight of a sphere of water 0.001 inch in diameter, 0.000,000,132,4 of a grain.
2. Weight of a sphere of gold 0.001 inch in diameter, 0.000,002,582 of a grain.
3. Weight of a sphere of gold 0.00x inch in diameter, $x^3 \times 0.000,002,582$ of a grain.
4. 200 grains of ore being taken for assay, the number of grains of gold per ton is found by $x^3 \times 0.2045288$, in which x = the diameter of the sphere of gold in thousandths of an inch. By taking 978 grains for assay, x^3 = grains of gold per ton.

To test the accuracy of the above figures a comparatively speaking large sphere of gold from an assay was

measured and found to be 0.593 mm or $\frac{100}{593}$ of a mm. in diameter, $59.3^3 \times 0.000,000,010,210,2 = 0.002129$ of a gram. When weighed on a very delicate balance, it was found to weigh 0.0021 gram.; and as this balance does not indicate beyond the fourth decimal, the results may be considered identical. This sphere indicated gold in the sample tried at the rate of 3 oz. 9 dwt. 13 gr. per ton.

The smallest sphere of gold I have yet measured was 0.024 mm. in diameter, and by applying the above rule the weight would be $2.4^3 \times 0.000,000,010,210,2 \times 15.43235$ (to convert grammes to grains) = 0.000,002,178, or a trifle over two millionths of a grain.

Spheres of silver may be obtained and measured in a similar manner. The boracic acid acts slightly on the silver, but the quantity dissolved is inappreciable, as the action is not prolonged. The specific gravity of silver being 10.53, the weight of 1.100 mm. would be $0.000,000,000,523,6 \times 10.53 = 0.000,000,005,513,508$ of a gram. In a test assay made with silver, the sphere measured 0.57 = $\frac{100}{57}$ of a mm., from which the weight deduced would be 0.0102096 of a gram., the balance showing the weight as 0.0010 of a gram.

Copper, lead, and other metals cannot be melted in boracic acid on platinum wire without dissolving to a perceptible amount, but may with care be melted in sodic carbonate, and by dissolving the latter in hot water, the sphere of copper, etc., obtained and measured.

Adelaide, July 6, 1886.

—Chem. News.

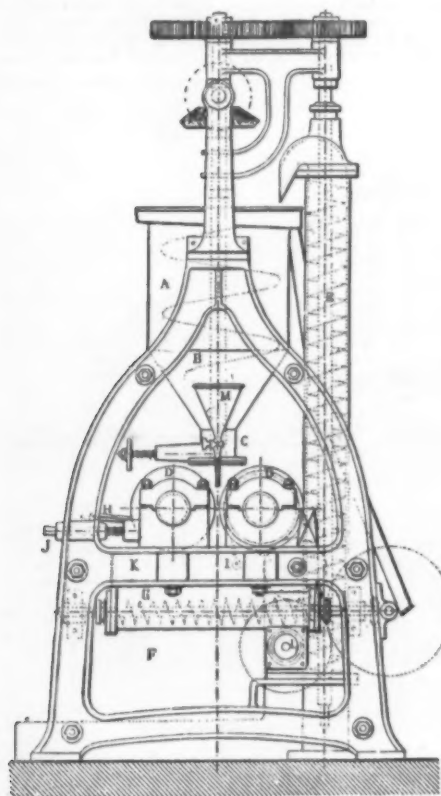
SALVAGE OF THE S.S. OREGON'S CARGO.

MR. I. J. M. MERRITT, JR., son of Captain Merritt of the Coast Wrecking Company, by whom the salvage was effected, narrating the story of the divers' work on the Oregon the other day, said:

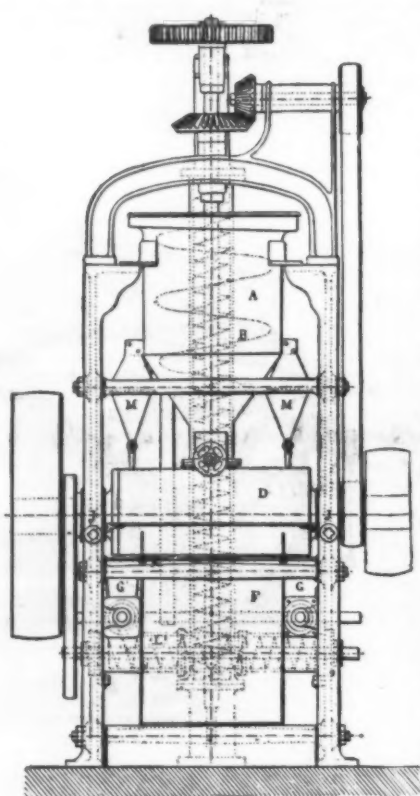
"When news of the wreck of the Oregon was received, and we were called upon, as we were immediately, we were off to her on the same day to examine how she lay, take soundings, and pick up what floating cargo and mail we could. March 17 we started out to go to work, but the weather was such that we could not do anything until the 29th, when we began.

"The Oregon lay in twenty fathoms of water. There is a popular idea that the agitation of the sea by storms is quite a shallow effect. But it doesn't take much of a storm to make itself felt sixty feet down, where the Oregon lay, as our divers were fully satisfied. And though it was possible to see dimly outside the hull, the darkness in the hold was perfect, so that the difficulties were great. Nevertheless, it did not take them long to find out that the Oregon was badly shattered. When she dived to the bottom, she careened over to the side upon which she had received her injury, and drove her nose down so deep in the sand that it was held there, while the power of the waves broke her in two close to No. 2 hatch, which was the largest and most important in the vessel, and slammed her down with such force that her bottom came up, and her decks settled down, so that her cargo was smashed between. Where she was broken in two, she had been literally twisted off; and though the recovery of goods from the great hatch at that point should have been the most important, it was in fact where least was saved, the magnitude of the opening having permitted vast quantities of cargo to float out, rise to the surface, and drift away.

"The salvage of the cargo was one of the greatest pieces of work of the kind ever performed, not so much on account of the depth of the water as of the locality and the steady continuance of the work. Lots of divers go down twenty fathoms for a few minutes at a time on some quick job, but staying down at that depth and working is quite a different matter. Some of our divers stayed down forty-five and even sixty minutes, but the usual time was from thirty to forty minutes. As a rule, we did not allow them to stay down as long as they wished to after they had become accustomed to the work, for there was always the danger that if a man was too long subjected to the pressure of 60 or 62 pounds to the square inch—that



IMPROVED WHITE LEAD PAINT MILL.



apparatus consists of an upper vessel, A, into which the white lead and oil are placed. This contains a revolving screw agitator, which presses the materials to the bottom of the vessel and causes them to mix and the water to be expelled from the white lead. When this has been sufficiently completed, the slide, C, is opened slightly and the mixture conveyed in a regular stream upon the grinding rolls, D. One of these turns in fixed pedestals, while the other can be set more or less close to the other by means of adjusting screws. The rolls turn at different speeds, the fixed roll making one revolution for two and a half turns of the other. This produces a grinding combined with a crushing action, as in roller mills for corn grinding, and results in an intimate incorporation of the lead in the oil, and imparts to the paint a great gloss. The paint is taken off the rolls by a horizontal steel blade, adjusted by two setting screws, and extending over the entire length of the cylinder. The receptacle below the rolls is divided into three compartments, by means of sheet copper divisions bedded to the rolls. The central compartment, F, receives the finished material suitable for sale.

The two side compartments, G and G', receive the overflow from excess of feed, or the material that has not undergone sufficient grinding, which is detached by two lateral doctors, I and I', at each end of the rolls, D. These compartments are semicircular at the bottom, and contain creepers, which convey the material to another cross trough, L, below the former. This contains two creepers, one with right and one with left hand thread, which bring the material together toward the middle and discharge it into the vertical elevator, E, also fitted with an archimedean screw, which lifts the imperfectly ground material back into the receptacle, A. The way in which the different parts are driven by gearing is evident from the illustration. By the screw propeller in the vessel the returned material is intimately mixed again with the supply contained in A, and ground over again on the rolls as before described.

In consequence of the superior action of the grinding rolls, this one machine replaces the series of machines

capsule and leading the last drop of water and the gold with a glass rod on to the plate. The water is drawn off by a piece of filter paper, and the plate gently heated till dry.

Having thus obtained the gold in a pure state, a bead is made of boracic acid on a platinum wire loop, and pressed on the gold while still red hot. The gold adheres without difficulty, and by heating the bead before the blowpipe the gold is obtained as an almost perfect sphere.

Should the resulting sphere of gold be very minute, it is better to measure it under the microscope while in the bead; but if large enough to be seen with the naked eye, it can be measured more accurately after dissolving the boracic acid bead in a watch glass with hot water and placing the sphere of gold on a glass slide.

The plan of measuring minute prills of silver and gold to determine their weight was first introduced by Harkort, who used an ivory scale engraved with two fine lines meeting at an acute angle and divided into fifty equal parts.

According to the fifth edition of Plattner's "Probirkunst," p. 520, Goldschmidt determines the weight of silver and gold prills by measurement with the microscope. As I have not access to the paper on the subject, his manner of preparing the prills for measurement is unknown to me.

Harkort and Plattner, in making scales for the determination of the weight of gold and silver prills, weighed prills corresponding to the larger divisions of the scale, and from their weight calculated the weight for the smaller divisions. These prills were taken direct from the cupel, and at the point of contact are flattened; but as the amount of flattening is not always the same, and hardly varies in extent with the size of the prill, and as the converging lines on the scale cannot be very sharply defined, this method is not capable of the same accuracy as where the almost perfect spheres are measured with a microscope.

No other flux seems to possess advantages equal to those of boracic acid for obtaining a sphere of gold.

had to be maintained at that depth—it might break him all up for several days."

"How break him up?"

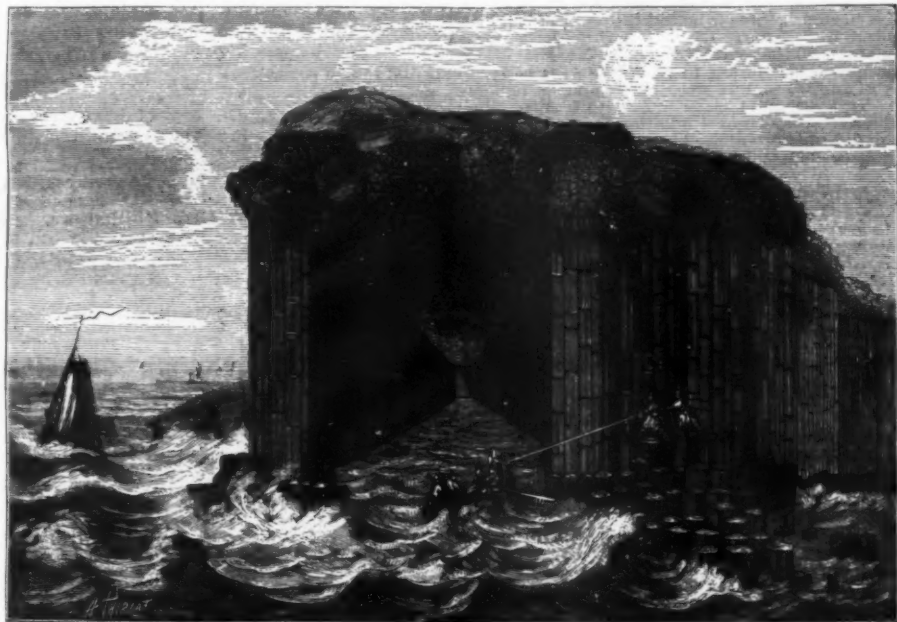
"Well, it seemed to paralyze them. Sometimes a man would come up with no control at all of an arm or a leg. It would hang as if dead. In a few days it would come all right, but the sensation, while it lasted, must have been rather disquieting. Then, when there was not actual paralysis of one or more limbs, there were apt to be sharp pains and aches. Some of the men who started in diving there could not stand the work, and had to give it up; but those who stuck to it seemed to grow accustomed to it, and did not complain at all after a little while. But they were an exceptionally good lot of men, and we took the best possible care of them."

"We saved an immense amount of stuff, but what it was, or what the condition in which it was recovered, we were not informed, and, in fact, it has not yet been ascertained even by the underwriters. We brought up much that was valueless after the soaking it had received. The divers could not tell, when they got hold of a box, what was in it, and selection of cargo was quite impossible. Some of the changes that had been worked by the water were surprising. Boxes containing dry goods that had been iron-hooped at the ends were so bulged out by the swelling of the saturated stuffs inside that they were round as hogheads. Before we were half through, there was nothing in the hold that would float. Everything was loaded with water. Even the white pine of the boxes was heavy as metal. And along toward the last everything got to smelling bad."

"Some of the hardest work we had was the getting out of the mail bags from the room where they were stowed in the bow, but we met that by simply cutting a hole through the iron side of the vessel, and getting at them directly; otherwise each one would have had to be carried out separately, for no tackle could ever have dragged them out by the tortuous way they would have had to go. There is a clock that, among other things, we fished out. It stopped, as you see, at nine minutes before one o'clock, the exact time that the vessel went down, no doubt."—*N. Y. Sun.*

FINGAL'S CAVE.

BASALTIC columns may be reckoned among the most wonderful of natural curiosities, and among those that



FINGAL'S CAVE.

excite to the highest degree the admiration of even such tourists as are most ignorant of the natural sciences. The volcanic regions of Central France, such as Auvergne, Velay, and Vivarais, are very rich in natural curiosities of this kind, but the most classic of basaltic columns are certainly those that form the noted Fingal's Cave, on the island of Staffa, one of the Hebrides, which I had the pleasure of visiting on the 13th of August last. I cannot too earnestly recommend the readers of this journal, who may have an opportunity of making a trip to Scotland, to make this charming excursion. The trip from Oban to Staffa is made on the magnificent steamers of the Macbrayne Co., of Glasgow, which leave every day except Sunday, and make the tour of the island of Mull, with a halt at Staffa to visit Fingal's Cave, and at Iona to visit the imposing ruins of a monastery which was founded by St. Columba, and was the cradle of Christianity in Scotland.

The island of Staffa is one of the smallest of the Hebrides. It is situated eight miles to the west of the island of Mull and seven miles to the north of the small island of Iona. The steamer stops at a few hundred yards from the island, and puts row boats into the sea. When the sea is calm, as it was on the 13th of August last, the landing is very easy. But it is difficult, and even dangerous, when the water is rough. A good road leads from the landing place to the cave, and one of the crew of the vessel acts as guide. The tourist walks over the tops of hexagonal basaltic columns that constitute a causeway for giants. Iron stairways have been placed in the worst places.

Fingal's Cave consists of basaltic columns like those of Vivarais, but of greater regularity and much more imposing. A plank walk permits of reaching the extreme end of the cave, which is 147 feet in length, 36 feet in width at the entrance, and 59 feet in height. The dome is about nineteen feet in thickness. The foaming waters of the sea enter the cave, but it would

be dangerous to visit the latter in a boat, and it is better to go on foot. A few of the columns are three sided prisms, but most of them are four, five, six, or seven sided. There is no need of torches, as enough light enters through the vast mouth of the cave.

This wonderful natural curiosity, alongside of which our most admirable (French) monuments are merely children's playthings, was as yet but little known at the end of the eighteenth century. Now, during the summer season, innumerable tourists daily visit it. It enjoys a wonderful celebrity, and is illustrated in all elementary works on geology. The figure which we reproduce herewith was made from an old and beautiful engraving dedicated about a century ago to the celebrated geologist Faujas de Saint Fond.

From the landing place that one touches when he makes the visit, a wooden stairway rises up above the cave, from whence may be had a fine view of the island of Mull, situated near the Ben More and Iona mountains, the latter of which is surmounted by the walls and square tower of the old cathedral founded by St. Columba.—*H. Courtois, in La Nature.*

THE POLICE OF BERLIN.

THE following description of the Berlin police system is given by a special correspondent of the *Journal des Debats*: Baron von Richtoffen, President of the Berlin Police, combines in his person the duties which in Paris are divided between the Prefecture of the Seine and the Prefecture of Police. He not only looks after the safety and health of the public, but has under his surveillance the streets, markets, and buildings, besides being responsible for public decency (*la police des mœurs*).

In relation to the Berlin municipality, which, by its excellent financial management, has shown itself worthy of the considerable administrative autonomy which it enjoys, the president of police exercises certain rights of control. He represents the State in its relation with the commune in the first instance, and is the organ of the executive power. The municipality bears a large share of the police expenditure, paying for the uniforms of the sergeants de ville (*Schutzleute*), and providing the buildings in the various localities where they are stationed. The State provides the pay of the men. That of the fire brigade comes out of municipal funds; though the firemen, like the *Schutzleute*, are under the orders of the president of police. The sergeants de ville

a police of safety, whose mission is to discover the authors of crimes and misdemeanors, and to keep strict watch over the dangerous classes, so as to prevent as far as possible the perpetration of offenses against person and property.

The head of the police of safety is Count Puckler, who by his own request has also charge of the department relating to public decency. The relations between abandoned women and criminals are such as to render necessary the co-operation of the two branches of the force. The agents of safety wear ordinary civil dress, and when they visit dangerous quarters, carry a revolver. The latter privilege has recently been granted to them in consequence of some serious encounters with armed criminals. The possession of a revolver is calculated to give the agent a greater degree of assurance; but he is strictly forbidden to use the weapon except in the last extremity. As I have said, an agent of safety is attached to each commission-ship, without counting those of the central brigade. The district agents are specially charged with the surveillance of dealers in old clothes, pawnbrokers, and all suspected persons having a fixed domicile. The town is divided for the purposes of this department of the force into eight arrondissements, each of which is under the direction of a commissioner. The division of labor which is so marked a feature of the Berlin police force is carried down to the dangerous classes. The ordinary Berlin criminal attaches himself to a specialty, and rarely departs from it. For instance, a pickpocket would no more think of breaking into a house than he would of stealing linen from a garret or pilfering from a cart. Crime being thus concentrated, greater ability is required on the part of the professional thief. This calls for a corresponding amount of cleverness in the police, and accordingly specialists are employed. One functionary will occupy himself entirely with cases of house breaking, another with thefts from furnished apartments and night lodging houses, a third with swindlers and gamblers, and a fourth with bullies, etc.

The same division has been followed in the Criminal Album, which I was able to examine, and which naturally is very interesting. Its usefulness is proved in this way: When a person comes to complain of having been robbed, he is shown the photographs of thieves specially addicted to the particular form of robbery. It often happens, however, that when the individual who has been identified from his photograph is arrested, the prosecutor is unable to clearly recognize him. Very curious is that portion of the album devoted to the wretched characters who live by extortion (*chantage*), of whom there are no fewer than a thousand in Berlin. You see there several photographs of beardless youths who have appeared as *figurants* on the boards of the Berlin theaters. The *service des mœurs* is carried out with extraordinary vigor in Berlin. The unfortunates are hunted down and their existence made intolerable.

All public halls and *cafés-concerts* must close at midnight, and these women are hardly permitted to frequent the Viennese *cafés*. Berlin has long had an evil reputation for the number of its bullies; but a great many have been got rid of by putting into force the articles of the Penal Code against procurations, and excluding such characters from certain quarters of the town. Those who are born in Berlin, or have their domicile there, cannot be expelled; but the quarters where they have the right to live can be restricted. The police tolerate a dozen or so of taverns and restaurants, the clients of which consist entirely of thieves, loose women, and bullies. These places, which are situated at the extremities of the town, near the gates, do not call for special remark. The police of safety at Berlin employs a rather larger number of informers (*vigilants*), who are recruited from the criminal classes.

SWEET POTATO ALCOHOL.

THE sweet potato (*Batatas edulis*) is, according to the *European Mail*, the main food crop at Barbados, where the yam is little known, whereas at Jamaica the converse is the case, the yam (*Dioscorea*) being very largely grown all though the interior hills, while the cultivation of the sweet potato is confined to a few places in the low lands. The following information was obtained by the editor of the *European Mail* from Mr. D. Morris, late Director of the Public Gardens, Jamaica, and now of the Royal Gardens, Kew. Since the large emigration of negroes to the Isthmus of Panama, there has arisen a considerable trade in yams between Jamaica and Colon, to the manifest advantage, in present cash returns, of the former country. Unfortunately, the cultivation of yams entails the cutting down of forest year by year, as good yams seldom do well, in the manner cultivated at Jamaica, except by the "rotation of land"—a peculiar negro mode of interpreting the European idea of "rotation of crops." Hence it is not very desirable, from a general economic point of view, to extend or encourage the cultivation of yams. With the sweet potato, however, it is different. This can be grown without the sacrifice year by year of valuable virgin forest, and it is, in many respects, a crop well adapted to all the low lands, not only of Jamaica, but also of the West Indies generally.

Besides being utilized directly for food purposes, it would appear that a new demand is likely to arise for the tubers of the sweet potato in connection with the production of alcohol. The first notice of the sweet potato being utilized in this manner appeared in a report to the Foreign Office given by Consul Hertslet on the trade and commerce of the Azores for the year 1884.

Owing to a variety of causes, it appears that cultivators at St. Michael's and other islands of the Azores, who had hitherto looked upon oranges as their staple production, were so disheartened by low prices and the diminished crops yielded by their trees that they resolved to clear their land of everything and plant it afresh with sweet potatoes. The whole of the crop thus raised was used in the preparation of alcohol. During the year 1884, 1,826 pipes of alcohol, of the value of £40,518, made from sweet potatoes, were exported from the Azores to Lisbon, and subsequently the trade assumed still larger proportions.

Encouraged by the success of the enterprise at the Azores, it appears that a French chemist, Monsieur A. Ralu, having much experience in chemistry as connected with distillation, and possessing extensive relations with the West Indies (Martinique), has taken out patents: 1. For utilizing as a commercial and in-

are only employed during the day time. At night the capital is confided to the care of watchmen (*veilleurs de nuit*), who wear a distinctive uniform, and are provided with a whistle and a saber. These men are on duty from ten o'clock at night till five or six o'clock the next morning; the final hour varying according to the season of the year. They number 500. The effective strength of the sergeants de ville is 3,500, of whom about fifty are mounted. All the sergeants de ville are old subordinate officers of the army, and are of a certain standard height. They must have passed nine years in the army, and employment is given only to those who have distinguished themselves by good conduct, zeal, and assiduity. They are respected by, and live on good terms with, the civil population, although their manner occasionally betrays their military training, and is not exempt from brusqueness.

The Berliner submits by force of habit to the injunctions of the sergeant de ville, and on military parade days one constable is sufficient to keep a large number of spectators in order. The morale of the corps is good, because the men know they are supported by both the public and the superior authority. The latter punishes all faults and negligences on the part of the force, and protects it when it is in the right. The sergeants de ville are under the orders of one colonel, eleven captains, ninety-three lieutenants, and a certain number of subordinate officers.

The town is divided into sixty-four districts. At the head of each district is a lieutenant of police, who has control over two subordinate officers, two telegraphists, two writers (*expeditionnaires*), twelve sergeants de ville, and one agent of safety (*agent de sureté*). The district is subdivided into small sections, each of which is confided to a sergeant de ville. The captain of police exercises supervision over several districts, which form his arrondissement, or charge. In addition to this outdoor police, which sees to the execution of laws and regulations, and maintains order in the streets, there is

dustrial substance sweet potatoes and yams, by means of desiccation and conversion into flour; and, 2, for distilling alcohol from the above flour.

In relation to the ordinary or Irish potatoes, white beetroot, and maize flour, sweet potatoes possess an alcoholic richness of 15.50 per cent., as compared with 8 and 9 per cent. of the Irish potato, and 4 and 5 per cent. in the beetroot. The value of raw sweet potato for distillation, and its superiority, both as to quantity and quality, over other substances, has been for some time known and recognized. The difficulty has been in extracting the alcohol on the spot; added to this, there is the danger attending its exportation, for it is impossible to prevent leakage, and the vapor of alcohol at 95° F. in hot climates is said to be inflammable. Alcohol, therefore, is assumed to be a dangerous cargo. As alcohol cannot, it is supposed, be made on the spot and exported to Europe, Mons. Ralu's patents aim at the preparation of sweet potato flour in the West Indies, from which afterward the alcohol may be distilled and utilized in Europe.

As already noted, one establishment for distilling alcohol from raw sweet potato exists at the Azores, and since it began work it is said to have doubled its plant, and all the alcohol it produces is sold in advance at Lisbon, where it is used for the fortification of wines. M. Ralu says: "The alcohol of which we have specimens is superior in quality to the best marks of France. The distillery obtains 12 per cent. (i. e., 12 liters of alcohol at 100° per 100 kilog. of sweet potato) of alcohol. We have experimented with the sweet potato of Algeria. They give 13-14 liters of alcohol per 100 kilog. The sweet potato of Martinique and Brazil has given 15 liters. There is here, therefore, a very rich material for distillation. Ordinary potatoes yield only 3 liters of alcohol per 100 kilog."

The objects sought by Mr. Ralu's patent involve the extensive cultivation of the sweet potato in the West Indian Islands, its desiccation by means of fruit driers, its reduction into a meal, and its export to Europe, where an almost unlimited demand exists for sweet potato meal for distilling purposes. The alcoholic richness of the sweet potato is shown by the following table:

	Frances.	Liters.
Wheat.....	19.75 to 21.50	28 to 30
Rye.....	15.50 to 16.25	22 to 23
Barley.....	17.75 to 20.00	24 to 25
Oats.....	17.25 to 19.50	20 to 21
Buckwheat.....	16.00 to 17.00	24 to 24
Maize.....	14.00 to 14.50	28 to 30
Rice.....	18.00 to 19.00	32 to 33
Sweet potato flour....	14.00 to 15.00	38 to 39

Maize, it will be seen, is the only cereal which is as cheap as the potato flour, but it requires 324 kilog. (714 lb.) of maize to make one hectoliter (23 gallons) of pure alcohol, while it requires only 335 kilog. (519 lb.) of the flour to make the same amount of alcohol. There is a great saving of time and combustibles when distilling from the flour as compared with the maize. Alcohol from maize costs 10 francs per hectoliter more to make, and when made sells at from 8 to 10 francs less than the alcohol made from the sweet potato flour.

The sweet potato at present cultivated in Jamaica is mostly intermingled with other plants in the provision grounds of the negroes. Hardly any is cultivated by Europeans. No definite area is returned as exclusively devoted to this cultivation, and no returns of yield per acre are available from authentic sources. A negro in the same ground will have yam (*Dioscorea*), corn (maize), sugar cane, and possibly, also, two or three other plants, such as bananas, plantains, cocoas (Cococasia).

Sweet potatoes thrive best in rich, friable soil, free from clay.

At the foot of the Liguanea hills, and, indeed, in most localities with the soil indicated above, they are found to thrive. They are easily propagated by slips or portions of the stem planted in rows or in hills. The roots come to maturity in three or four months, and the cultivation is continued by covering up the stems when digging up the more perfect roots for use. The crop comes in practically all the year round. There is no regular season for it, and hence it can be best harvested by examining the state of the roots, and taking out those that are found perfectly ripe. The crop may be gathered at least three or four times in the year, but as to the amount or value of each cropping no data are immediately available.

If the cultivation were undertaken by sugar planters, and large areas were planted with sweet potatoes, there is little doubt that in Jamaica they might be grown as advantageously and as successfully as anywhere.

ON LION-BREEDING.*

THE Gardens of the Royal Zoological Society of Ireland have become famous among zoological gardens for their breed of lions. While here and there among the zoological gardens of the world a lion cub is born, none save those of Dublin can boast of a period of lion-cub production of nearly thirty years' duration, or of the extraordinary success of the birth of 131 cubs. This being so, we are indebted to Mr. V. Ball for a history of the subject, which has been published in a recent part of the *Transactions of the Royal Irish Academy*. The subject is one of interest in several ways, and the following short abstract of the details will call our readers' attention to it.

In 1855, a pair of lions from Natal were purchased for these Gardens. The exact relationship of these appears to have been unknown, but their first litter was born in 1857. From 1857 to 1885 we find a total of 131 cubs born, of which 21 were either born dead or died shortly after birth, and 110 were reared, 86 of these latter being sold, greatly to the profit of the Society and to the advantage of very many of the

zoological gardens of Europe, Asia, and America. These 131 cubs were the offspring of nine lionesses and four lions. Of the latter, one, "Natal," was the father of 49 cubs; and another, "Old Charley," who was a son of "Natal's," was the father of 46; while of the former, one, "Old Girl," who was born in the Gardens in 1859 as one of a litter of five, was the mother of no less than 55 cubs, of which 49 were reared. This prolific lioness died at the age of 16 years, apparently of old age.

The facts given by Mr. Ball in one of his very carefully compiled tables seem to indicate two periods of the year at which lionesses in a state of semi-domestication produce their young. While the absence of any well-authenticated information as to the period of the year in which lion cubs are born when in a state of nature is quite remarkable, yet Mr. Ball ventures the fairly safe surmise that considering the period necessary for the rearing and education of a cub to be at the least a year—for the cub is often learning to kill its prey when over a year old—it is most improbable that lionesses have more than one litter in a year when in a wild state; but he thinks it probable that the geographical surroundings of the parents may alter this period, and that it may be in the autumn season in the tropics, when the great heats and droughts of summer are over, and in the spring season in more temperate climes, where the summer warmth would be of service to the young offspring; and he very ingeniously speculates that the two periods of maximum production, as observed in the lionesses in the Dublin Gardens, may have been inherited from two corresponding periods, the result of climatal conditions in a wild state. Another remarkable phenomenon comes to light on comparing the curves of production, when modified into curves of conception, with the monthly curves of temperature for Dublin. In doing so, the maximum curve in the one case is found to closely approximate to the maximum curve of temperature, i. e., June and July, and the second maximum curve corresponds to the period of lowest temperature, i. e., December and January. But it will be remembered that then the animals are kept in well-heated houses, so that this period, as to temperature, may, though the temperature be artificial, be compared to the other when it is natural.

The cubs, when born, are noted as distinctly spotted with dark brown on a ground color which is rather light brown than fulvous; from about one to three months they are perhaps most distinctly defined; and though along the back the spots are somewhat quadrangular in shape, there is no indication of actual bars or bands.

In reference to the sexes of the cubs, Mr. Ball is able from accurate information to record the sex of 130 of the cubs, and we find 74 were males and 56 females, giving a majority of 14 males in every 100 cubs. This is an interesting and novel addition to our knowledge of the natural history of the large carnivores.

No lion or lioness lived in the Gardens for a longer period than 16 years, and it seems probable that 12 to 14 years is the average duration of lion life. The cases so often referred to of lions living to an age of 30 to 30, or the case of "Pompey," who died in the Tower in 1780 at the age of 70, stand on no scientific or even reliable evidence.

Under the heading of "The Cause of Success in Breeding," we find some valuable suggestions as to the keeping of these splendid carnivores; but we searched in vain for the secret of success. Horse flesh is evidently not dear in Dublin, as the annual cost of the food of an adult lion, being for the most part horse flesh, only came to £15 in 1885. A series of tables accompanies the memoir, and some illustrations of the cubs of the lioness "Queen," born April, 1885, from drawings by Mr. Thomas.—*Nature*.

RECIPROCAL RELATIONS OF THE GREAT AGENTS OF NATURE.

A NOTICE of Prof. Klein's comments on the Inaugural Address of Prof. Clausius as *Rector Magnificus* of the University of Bonn, and on M. Hirn's recent work, "The Notion of Force." Clausius explained the difference between the ideas anciently held in physics concerning the agencies of nature, such as heat, electricity, and light, etc., and those which are now substituted for them. Without ignoring the connection between these agencies, he shows the impropriety of such expressions as "transformation of heat into electricity and of electricity into light." The propagation of radiant heat and light may very probably be explained by an action of electric forces, and that very probably electricity itself may be substituted for the ether supposed to fill and pervade both space and all bodies. Prof. Clausius suggests that besides ponderable matters, there exists only one substance, and that the totality of phenomena may find their explanation by means of the varied movements of this substance. Prof. Klein thinks that M. Hirn has taken a further step by considering "force" taken in general as a class of elements specifically distinct from so-called ponderable matter, establishing that the ancient imponderables of physics, electricity, heat, etc., are not particular species of matter or vehicles of force, but forces properly so called forming a class in common with the cause of gravitation.—*E. Schroeder*.

ON THE SYNTHESIS OF ACTIVE CONINE.

LADENBURG has repeated his experiments upon the synthesis of conine upon a larger scale, and has confirmed his former results. The α -allylpyridine was prepared by heating the carefully purified α -picoline in sealed tubes with paraldehyde to 250°-260° for ten hours. From 1 kilo. crude α -picoline, by repeating the process, 380 grms. pure α -picoline and 45 grms. allylpyridine were obtained. Its reduction to α -propylpyridine was effected by means of sodium, and yielded nearly the theoretical quantity. The hydrochlorate crystallized in white silky needles permanent in the air and fusing at 208°-205°.

The base itself shows the closest similarity to conine, agreeing with it in odor and in its behavior to water, in its specific gravity (0.8626 at 0°), and in the properties of its salts, especially the double chlorides of gold and of platinum. To still further establish the identity of these bodies, the author converted the α -propylpyridine into conyryne, and observed identically the same

fluorescence in the crude product, though the pure substance was free from it.

The platinum salt had the same fusing point and the same crystalline form. The physiological action of α -propylpyridine is identical with that of conine, as proved by Falek. The author believes that he has established the complete identity of these two substances, and therefore has prepared for the first time by pure synthesis a vegetable alkaloid.—*Ber. Berl. Chem. Ges.*, xix., 2578-2583, October, 1886; *Amer. Journal*.

HYDROGENATED PALLADIUM.

ACCORDING to Professor C. G. Knott, in a paper read recently before the Royal Society of Edinburgh, if a wire of palladium be dipped into an electrolytic cell so as to become hydrogenated throughout half its length, and the ends of the wire be connected to the terminals of a galvanometer, a current will be obtained in the latter when a flame is allowed to play upon the middle of the wire at the limit of the hydrogenated and non-hydrogenated palladium. This current is due to a thermo-electric effect between the two portions of the wire. The current rises to a maximum, then diminishes to zero as the temperature of the junction is further increased to a red heat. There is no such current during the cooling of the wire.

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* "Observations on Lion-Breeding in the Gardens of the Royal Zoological Society of Ireland," by V. Ball, M.A., F.R.S., Director of the Science and Art Museum, Dublin, and Hon. Sec. of the Royal Zoological Society of Ireland. *Transactions of the Royal Irish Academy*, vol. xxviii., Part 2d, August, 1886.

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